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E'LECTRONICS
The Maplin Magazine
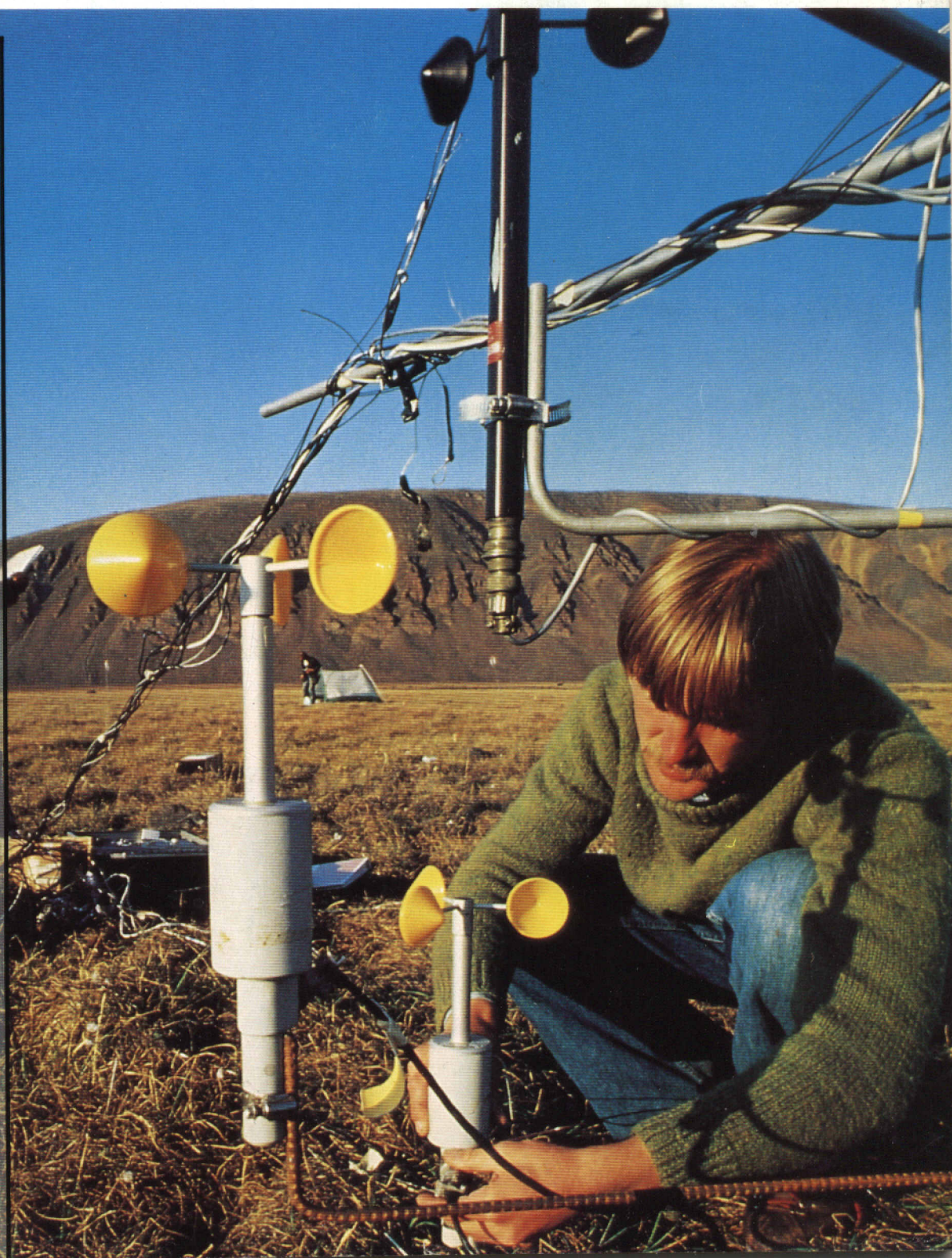
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Construct a wind speed and direction indicator.

Digital speech expansion boards! Playback only & EPROM modules.

Data File on the LM13700, transconductance operational amplifier.

RS232/TTL converter and digital panel meter to build. Full details given!

Articles on telephones, loudspeakers, VAD's and more.

CONTENTS

APRIL TO MAY 1989 VOL.8 No.31

EDITORIAL

■ Welcome to the third edition of the new style 'Electronics'. Many people have taken the time and trouble to write to me about the new format, most of which have been exceedingly complimentary! A few adverse comments were also received, these are being looked into and hopefully will be resolved. In this issue we feature the start of a new weather station project which should be an enjoyable project for many people to build, it would also make an excellent schools project for the kids! The first part shows how to construct wind speed and wind direction indicators. Also in this issue, we have the follow on boards for the digital record/ playback system. This project has already proved to be very popular as can be seen in the letters page, which shows just a couple of the letters received about it. Other 'goodies' to look for in this issue include an RS232/TTL converter and a digital panel meter. I'm sure you'll find many items of interest to you in this edition, and I hope you enjoy your copy of 'Electronics' as much as I've enjoyed putting it together. Until next time, read on and enjoy!

R.T.Smith

PROJECTS

FEATURES

REGULARS

LOUDSPEAKERS
THE FIRST 111 YEARS

Part 4

by J.M. Woodgate B.Sc.(Eng.), M.I.E.R.E., M.A.E.S., M. Inst. S.C.E.

The Frantic Seventies

The eighth decade of the century saw an enormous amount of activity in the loudspeaker field. This occurred both in the laboratory and the theoreticians' ivory towers, as well as in the grimy marketplace. However, the science and the exploitation were often going in quite different directions.

The decade opened with a strong public interest in quality audio. Support for the London Audio Fair had been great enough in 1969 to warrant a second event at Olympia in 1970, and this was a considerable success, with plenty to interest both the high-fidelity enthusiast and the general public. A contemporary commentator noted that the lecturers at the Fair's seminars were virtually unanimous in supporting the natural reproduction of live music as the goal, although it was noted that an American manufacturer's (JBL) demonstrations were much too loud and suffered from deliberate bass and treble boost. The company still adopts the same measures, and must at least be given credit for consistency! By contrast, Bell and Howell, showing the Acoustic Research AR4x, AR6 and AR3 earned praise for a realistic demonstration. KEF demonstrated a new 'Cadenza' loudspeaker with a 200mm bass unit and a passive radiator. Leak showed a group of three models with 'sandwich' diaphragm drivers, and Wharfedale introduced two new models the 'Triton' and 'Aston'. A little cloud appeared on the horizon, though, in the form of two models from Sansui, one of the first Japanese companies to try the difficult British hi-fi (as opposed to hi-volume) market. Sansui always seemed to be more sensitive to the individual requirements of the British market than other Japanese companies, possibly as a result of the poor reception which these initial offerings received. This was partly due to the design problems of their very shallow cabinets and partly to the unacceptable 'purple prose' with which the products were described. A few omnidirectional loudspeakers were shown, but their defects were well-explained in the technical press and they did not long survive. The most fiercely promoted of these products was the Sonab, featuring a

Photo 1. Goodmans Audiom 12P-D, a typical 300mm bass driver for sound reinforcement or electronic music.

personality cult based on the designer Stig Carlsson. A British magazine review came to unfavourable conclusions on build quality, stereo imaging and general performance.

Papers Galore

That the '70s were a very busy period is shown by the fact that the Audio Engineering Society has found well over forty of its Journal papers from that decade worthy of including in its Anthologies of papers on loudspeakers. Early papers from the period include Klipsch on modulation distortion and Barlow on the sandwich cone developed for Leak. These were followed by Richard Small on constant-voltage crossover networks and the inspired reprinting of Neville Thiele's ten-year old work on the theoretical design of vented boxes. More work on crossover design was published by Ashley and Kaminsky, and by G.L. Augspurger, whose trenchant comments on the weirder U.S. loudspeaker patents are always worth reading. All these were published in a single year (1970).

Quadra-PHONEY

Not content to continue giving the public what is so clearly still wanted, the industry began in 1971 a Gadarene rush into four-channel sound, goaded by CBS with its 'SQ' system. It is to be hoped that this sort of thing couldn't happen again, because it is understood that one doesn't introduce new gizmos until the sales of existing products begins to sag.

Unfortunately, there are grave signs that we are going to see a similar fiasco over the sound side of HDTV, because most of what has been learned about stereo and directional sound fields, culminating in the 'Ambisonics' theories and system, since 1970 is being studiously ignored in favour of impracticable three and five-channel systems originating in Germany and Japan.

As far as the public (and, indeed, uncommitted manufacturers) were concerned, total confusion reigned, as 'SQ' was followed by 'QS', 'CD4' and a host of other, incompatible systems. The initial success of 'SQ' was founded solely on hype, and, apart from the fact that it was not a satisfactory system, the major problem of how to accommodate four loudspeakers in the average room was never addressed, let alone solved. A couple of years of this nonsense was enough to produce a swift collapse of the market and of public interest in audio. Other, marginally unhelpful promotions were an omnidirectional design released by Radford in 1971, in the face of the accepted defects of the concept, and a 'bi-directional' loudspeaker, the 'Dimension 8' from Goodmans in the same year. When acknowledged reliable manufacturers produce unacceptable products, it is not surprising that confidence generally is jolted. Still, it takes time for disillusionment to spread, and two more years were to elapse before the bubble well and truly burst.

Photo 2. Veiw of the cone of the Goodmans Audiom 12P-D, showing the central 'whizzer' and dust-cap.

The Time Dimension

1971 saw the publication of Richard Heyser's work on loudspeaker signal arrival times. It has already been mentioned (Part 3) that Heyser's papers are often difficult to comprehend, but there is no doubt that the work cast a new light on many unsuspected defects of existing designs, and pointed the way to improvements. In effect, Heyser showed that a loudspeaker may not begin to emit sound at the instant the signal is applied, and that any delay is a function of frequency (and perhaps amplitude as well). This publication was followed by a paper by Small on simplified measurement of loudspeakers at low frequencies. Another important paper was 'The sound field in home listening rooms' by Allison and Berkovitz. The well-known influence of the room on the sound of a loudspeaker had been resistant to analysis because of complexity. This paper did not resolve that problem but indicated, perhaps, directions to the start of a path along which a solution might be found.

Photo 3. A German-made ITT 125mm bass driver for a small high-fidelity system, having a modified polystyrene cone and a neoprene surround.

Punting Towards the Weir

The 1972 London Audio Fair was marred by squabbling between manufacturers, resulting in several going off to play by themselves, thereby benefiting nobody. Clearly, sales were still so good that they had time to waste in internecine argument. Meanwhile, electrostatic drivers were undergoing a revival in the USA, either along or in combination with electrodynamic units in full-range systems. There was not so much new in Britain: most manufacturers were struggling to keep up with demand. Nevertheless, designs were improving as the work of Thiele and Small became more widely known.

Secrets of the Closed Box

Richard Small published his theoretical analysis of closed-box systems in 1972, and these papers, while expounding the theory, also relate directly to practical measurements and

Photo 4. A Japanese 90mm full-range driver in an in-car 'pod' enclosure.

design techniques. Counsequently, the new theory could be quickly applied by designers all over the world, and a general increase in performance resulted. Small showed that a closed-box system behaves as a high-pass filter, and its performance can be predicted in many respects, provided the drive unit is not driven into non-linearity and that the enclosure is substantially free of panel resonances. This latter subject was treated in a paper by J.K. Iverson, published in the following year. Meanwhile, Arthur Bailey produced a transmission-line design for home-construction, and Stan Kelly published an exhaustive survey of current loudspeakers and technologies in 'Wireless World'. This included a table of products, over 200 in all, ranging in price from £8 to £350 each.

Ribbons Again

That new product ideas were not entirely sacrificed to the satisfaction of demand for 'more of the same' was illustrated by the development by Fane Acoustics of a twin-ribbon tweeter, launched in January 1973, and intended to replace the 'Ionofane' (see Part 2). The two ribbons were horn-loaded and the driver would handle 30W above 1700Hz, producing a sound pressure level at the horn mouth of 115dBSPL. Interest in audio was still enough in 1973 to support both Sonex in spring and an Audio Fair in autumn, as well as Harrogate as a specialist high-fidelity exhibition. At Sonex, IMF launched a transmission-line system with a supplementary active sub-bass driver, and Gale Electronics introduced the distinctive GS401 closed-box system. This contained two 20cm bass drivers, a 10cm mid-range and a 19mm dome tweeter. This product achieved most notice because of its unusual styling, with a black centre-section and chromium-plated end pieces. Philips, in September, launched a loudspeaker system with motional feedback derived from an accelerometer mounted in the centre of the bass driver cone. There was a great deal of misguided promotional ballyhoo associated with this product, which did Philips' uncertain image as a hi-fi

manufacturer no good at all, and obscured the real merits of the product. At the Audio Fair, KEF introduced the first version of their R104 system. This was a 3-way design, with an elliptical bass driver, a coupled 20cm bass/mid-range (!) and a dome tweeter. This product benefitted from the computer-aided design techniques pioneered by KEF, in which driver and system responses are measured digitally. This allows extensive analysis of the results, which can, with care, be more accurate than those obtained by analogue methods, and gives the capability of matching drivers and dividing networks so as to control system response with a decibel or so at any frequency.

Vented Boxes

1973 saw the publication of Richard Small's extension of Neville Thiele's work on vented box systems, which also reviewed work by other authors since 1961. D.B. Keele suggested methods of measuring important low-frequency performance characteristics in the near-field, under normal room conditions. After the storm of papers in the early years of the decade, it is not surprising that the number of new publications was reducing later.
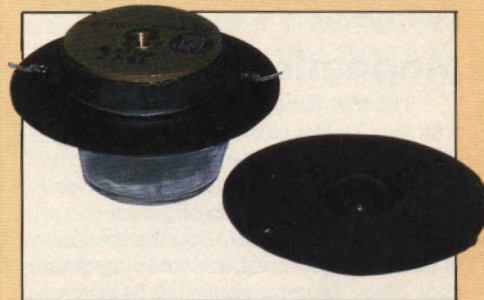
Photo 5. An Audax 19mm dome tweeter, similar to that used in the up-dated Wilkinson DIY design.

Crisis Year – 1974

The year opened with complacency evident in the industry, and it closed with overt panic in many minds. Sales volume plunged alarmingly for many companies: the usual autumn upturn was delayed until November and was far below expectations in volume terms. Top-class high-fidelity fared better, as it usually does, because the clientele is much less fickle. The Harrogate show was bigger than ever, with 80 exhibitors, and began to suffer from the insensitive approach to demonstrations that was already marring the London events. However, the innovations were largely outside the field of loudspeakers.

Hide in the Back Room

In spite of, or perhaps because of, the market mayhem, more papers were published in 1974. H.D. Harwood, then of the BBC, discussed motional feedback, clearly having been provoked by the Philips product. He disclosed that

P.G.A.H Voight had patented a bridge-derived velocity-feedback arrangement in January 1924, ten years before Black and Nyquist put negative feedback on a sound mathematical basis. Sykes (1926) patented feedback from an auxiliary voice-coil or a microphone, while Trouton (1928) derived velocity and acceleration feedback from capacitive sensors. Harwood was generally sceptical of all the claims for feedback systems, except the reduction of non-linearity distortion at all but the highest levels. However, he endorsed the accelerometer, used in the Philips system, as a preferred device for deriving the feedback signal. J. Dinsdale published a series of articles on the design of (high-fidelity) horn systems, while the problems of living with them (and their designer) were well expounded by Heather Dinsdale. Jimmy Moir produced a definitive text on Doppler distortion (see Parts 2 and 3), while Rank Radio (the once and future Wharfedale) announced the development by Dr. Peter Fryer of laser holographic techniques for investigating cone break-up and other mechanical motions. To round off the year, H.D. Harwood produced a study of the non-linear behaviour of air in enclosures, and R.F. Allison published work on the interaction of the loudspeaker with the room boundaries.

Magnetic Liquid

The following year, 1975, opened with the disclosure of 'ferrofluid' by Phillips Research Laboratories. This suspension of magnetic ferrite particles in a stable, heat-resisting oil, soon became useful in controlling the motion of tweeter voice-coils, and keeping them cool. Many attempts to use the fluid in bass drivers resulted in the designer acquiring a red face, underlying a black, spotted one! Sony showed a pair of exotic loudspeaker designs with carbon fibre composite cones, one model with a price-tag of £1500. Minimum-phase designs also began to appear, from Technics and National Panasonic initially, and Bang and Olufsen. At the Berlin exhibition, several motional-feedback designs were shown, but the technique did not survive for much longer. It is, however, about due for a revival!

Conventional Audio

In March 1975, the 50th Convention of the Audio Engineering Society was held in London, and more papers were presented on loudspeakers than on any other subject. Topics included bass driver design, the application of holography, new measuring techniques and the Bang and Olufsen minimum-phase 3-way design. In a second session, Mike Berman and Lawrie Fincham presented initial papers on the digital measuring techniques developed at KEF. Several papers dealt with the properties and defects of enclosures and crossover networks. At the 52nd Convention, in New York, R.F. Allison presented a

second paper on listening rooms.

Halfway through the decade, business was not good and the painful withdrawal from the 4-channel fiasco was underway. At the same time, very much more was understood about practically all aspects of design than even five years before.

Risen Sun

By 1976, Japanese brands were well-established in Europe, both in high-fidelity equipment and in 'cooking' audio, represented by the 'music centre'. But there was no general acceptance of Japanese-designed high-fidelity loudspeakers, and loudspeakers for music centres were often made in Britain, mainly because the economics of shipping from Japan were unfavourable. Uncertainty in the industry led to the ill-fated HEDA combined television, audio and domestic appliances exhibitions at the NEC, in which serious audio was eclipsed by other, high-powered interests. Even Harrogate was uninspiring, the only notable item being the number of 'linear-phase' loudspeakers on show.

Phasing up to Facts

In the literature, there was much discussion on the meaning and importance of the phase-response of loudspeakers, and methods of achieving any desired response. Prominent contributors were H.D. Harwood and James Moir, both extremely sceptical of the importance of controlled phase-response on the basis of theoretical analysis and experimental support. However, others such as Michael Gerzon, K.A. Hodgkinson and S.K. Pramanik were quite definite that phase-response needs to be controlled. There was agreement that inter-channel phase-differences in stereo systems are significant, but that is (usually) a separate matter. The supporters of phase-response control produced cogent criticisms of experiments that gave negative results, mainly based on the premise that tests using programme material that has already been scrambled in phase in the recording process are unlikely to show up any defects in the loudspeaker under test! Harwood also published a valuable survey of less-familiar defect mechanisms in loudspeakers, in 'Wireless World' of May 1976, and this article should be required reading for all loudspeaker designers. Possibly the most significant AES paper was one by S.H. Linkwitz on active crossover networks, which drew attention to the need to take into account the phyiscal separation between drive-units. Another paper, by L.J.S. Bradbury, developed a theory for the behaviour of fibrous filling materials in enclosures.

Stagnation

The first half of 1977 was not a good time for the audio industry, and things did not improve much, later in the year. One

product which did excite some interest was the cylindrical 2-way system, marketed by Jim Rogers as the JR149. This used thin sheet steel for the enclosure, which was sufficiently stiff and non-resonant by virtue of its shape. The end-caps were also metal, and were made non-resonant by stressing with an axial tension rod. This year was also notable for the emergence of the mystical, or 'musicality' school of audio, which is still being so viciously exploited (in terms of cables at £50 per metre, for example!). Peter Baxandall attempted to nip this unwelcome development in the bud ('Wireless World', November 1977), but there has clearly been too much vested interest behind the movement for it to be easily scotched. Proponents would do well to remember that 'You can fool all the people. . .'

DIY, in a Listening Room, with Three Drivers, on Impulse!

'Wireless World' also published an interesting design for a DIY bookshelf loudspeaker, by J.H. Wilkinson. This was notable for its quite complex crossover design, with 4th-order characteristics. Jimmy Moir returned to the typewriter with an article on the interaction of loudspeakers with rooms, stressing the differences in room-mode excitation that occur with the loudspeaker in different positions, and the relatively modest subjective effects of room-boundary reflections, except those from a boundary close behind the enclosure, under normal conditions. He also drew attention to the fact that, in balancing the frequency-response of the loudspeaker, the designer will have had to make assumptions about where and how it will be mounted in the room, and should disclose those assumptions to the user! Otherwise, excessive or insufficient bass response is all too likely. Audio Engineering Society papers included one by Erik Baekgaard, describing the elgant 'Filler Driver' 3-way system design developed by Bang and Olufsen, while Fincham and Berman produced their first definitive paper on the use of digital techniques for the measurement of loudspeakers. This involves the measurement and digital storage of the impulse response of the unit, followed by the calculation of the amplitude and phase responses by means of the inverse Fourier transform. It is an inherent assumption that the whole system has a linear amplitude response. Minor departures from linearity do not, however, have a disastrous effect but must be allowed for, as must other departures from the ideal conditions. It is notable that, whereas defects in an analogue measurement may have subtle effects (and therefore pass unnoticed), defects in a digital measurement are liable to have profound effects (such as superimposing a wave, or even a comb-filter response) on the results

obtained. When all, or most, of the problems have been solved, the technique is very powerful. At a public demonstration of the method in a hotel bedroom, it proved possible to reduce the amplitude of the test pulse so that the response was hidden in noise, and then average out the background (foreground!) noise over 60 tests, so that quite an accurate result was eventually obtained. Pointless, but an indication of what could be done with this powerful tool.

Raving over Reviews

1978 opened with a disturbance, promoted by several manufacturers declining to submit products for review by subjectivist reviewers. While part of this problem, that of reviewers acting as consultants and then, apparently independently, reviewing the products they had helped to design, was settled to some extent, but the subjective movement suffered no real set-back, and flourishes still. The controversy rumbled on throughout the year, until everyone was bored with it, and resolved very little. This argument largely overshadowed the new product introductions, which were in any case relatively few and none were revolutionary.

Barlow, Linkwitz, Adams – and more Linkwitz

Papers and articles published in 1978 continued to indicate the amount of commercial and private research which was going on behind the scenes. D.A. Barlow wrote on coloration due to resonances, and how they may be eliminated, while S. Linkwitz produced a series on system design for 'Wireless World'. This used active delay and crossover filters, the latter being of the 'Butterworth-squared' type, now known as 'Linkwitz-Riley' filters. These have the considerable advantage of a 4th-order rate of cut-off (24dB/octave), with a flat total amplitude response and give an acceptable vertical directional response. The system consisted of a sub-woofer and two two-way satellites, using KEF drive-units. No doubt capable of high performance, the electronics part was of quite significant complexity, having some 34 op-amps involved. Glyn Adams (later of B and W) produced an AES paper on computer-aided design of systems, while Linkwitz also wrote on passive 'Butterworth-squared' filters.

The Second Hi-Fi Revolution

1979 saw the second serious attempt to sell high-fidelity equipment to the mass-market. Prompted by Japanese manufacturers, most of the mass-market suppliers (which effectively meant colour television manufacturers) began to offer high-fidelity products, with varying degrees of expertise. There is an astonishing difference between selling television, or even 'cooking' audio, and selling hi-fi, as many people found – the hard way. Some of the offerings were good, but inexpertly marketed, while some did not warrant any special effort in that direction! Loudspeakers are undoubtedly the most difficult products to get right, and nothing offered by the newcomers to the market will have given a moment's concern to the established suppliers. Public reaction was in the nature of polite interest, rather than wild enthusiasm, but a respectable volume of sales was achieved, and disillusionment created by the quadrophony fiasco seemed to have vanished. Philips and Sony, of course, were working hard on Compact Disc. Most of the loudspeaker products were smallish two-way systems, but some larger ones, often 3-way were also evident. Another development was the growing interest in in-car equipment, with better cassette machanisms and higher amplifier powers. Some truly astonishing loudspeaker designs emerged, some of which were even more astonishing when listened to! Others were quite good.

What the Papers Said

That not everyone was willing to buy 'off the peg' was demonstrated by the publication in 'Wireless World' of an updated version of Wilkinson's bookshelf system with its exotic passive crossover. A new enclosure, with non-parallel walls was introduced, together with a new tweeter and associated equaliser, the original driver being no longer available. James Moir offered a review of the effects of system directivity on sound quality, without introducing any new insights, and wrote up a new method of measuring sound power, which has not, it appears, been widely adopted for loudspeakers but is often used to measure the noise power output of machinery. In the AES Journal, J.M. Kates wrote on cabinet reflection effects, and A. Rosner on current disco system techniques. Predictably, loudspeakers were considered the most critical and difficult elements. J.N. White produced a most
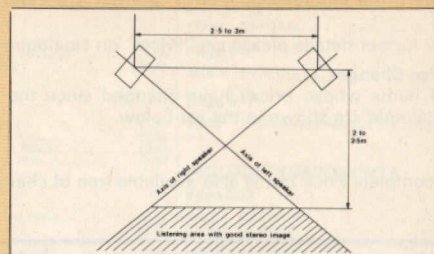

Figure 1. 'Brittain' loudspeaker layout for optimum stereo image showing the area of good stereo imaging.

useful paper (November), confusingly titled 'Loudspeaker Athletics', giving guidance on using Thiele alignments with drivers that may, at first sight, seem to have unsuitable characteristics. Since this applies to the majority of the lower-cost drivers (which have too high a Q), White's paper could be very helpful. Lawrie Fincham wrote on the extensive use made by KEF of computer measurements and data collection in the production testing of drive units and their close matching for high-quality systems. Daniel Queen wrote on loudspeaker radiation patterns for stereo. This latter subject had not received anything like the attention that it should have, and the truth of the matter is even today not widely known. Queen's paper deals mainly with experimental results, although there is some analysis, and both he and Kates (in the following year, so really a matter for Part 5) did not refer to the work of Brittain and Leakey (published in 'Wireless World' in May 1956!), which first indicated that, for stereo perceptible elsewhere than 'on the white dot' (i.e. at the centre, well in front of the loudspeaker base-line), a controlled and rather narrow directional response is required at all frequencies, AND the loudspeakers should each be aimed at the opposite end of the listening area (i.e., pointing inwards quite sharply), see Figures 1 and 2. It is astonishing that this

Figure 2. Optimum directional response for stereo loudspeakers (after Brittain). Nearly all direct-radiator loudspeakers are much less directional.

second simple fact, easily verified with practically any system whether the directional responses are correct or not (provided that the loudspeaker systems are not completely omnidirectional), is either not known, or not accepted, universally! Why don't you try it, if you haven't already?

Wind speed & direction indicators

by Dave Goodman

Photo 1. The wind speed cups.

Introduction

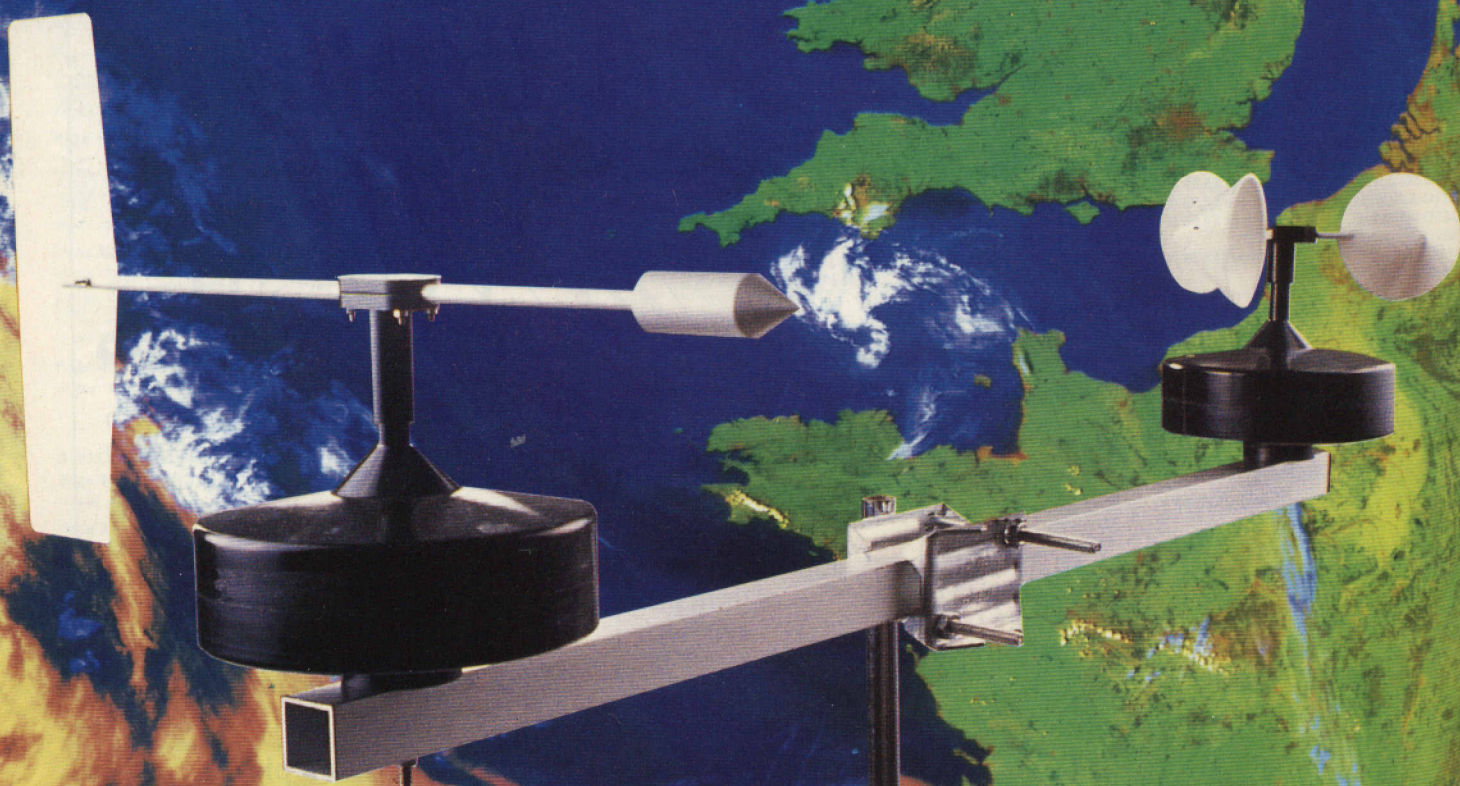Meteorology, or the study of phenomena of the atmosphere (the weather to us!), must be the one particular science that most of us 'dabble' in. Pet theories involving corns on toes, squeaky knees and back ache, have heralded weather conditions throughout history and I suspect that the old rhyme about 'red skies and shepherds' is a familiar one to many people!

One thing for sure is that the weather can't be easily changed, but it can be easily measured - with suitable instruments of course - and the first part of this project covers the construction of a wind speed sensor (anemometer) and a wind direction sensor. Part two will have details of the decoder and display electronics and will be published in a future issue.

There are various methods by which wind speed can be measured and common systems, such as this one, are based on revolving cups as can be seen in Photo 1. Each cup, behaving like a sail, catches the wind and being connected to a central shaft they spin faster or slower according to forces exerted by the wind. Also connected to the shaft is a coded disc, as it revolves sensing electronics translate rotation into frequency. Unfortunately wind speed is rarely constant and tends to gust in short bursts. Due to such side effects as friction, mass and inertia, the rotating parts cannot instantaneously follow changes in wind speed, therefore, the final result is an average wind speed indication.

Wind direction relies on the time honoured weather vane principle, whereupon an arrow shaped pointer is allowed to revolve laterally with the wind. A tail fin tends to block the clear passage of moving air and is therefore forced into a position of least resistance. The arrow tip is weighted, as can be seen in Photo 2, to damp the otherwise continual oscillation that would ensue in strong winds and also points to where the wind is going to - not
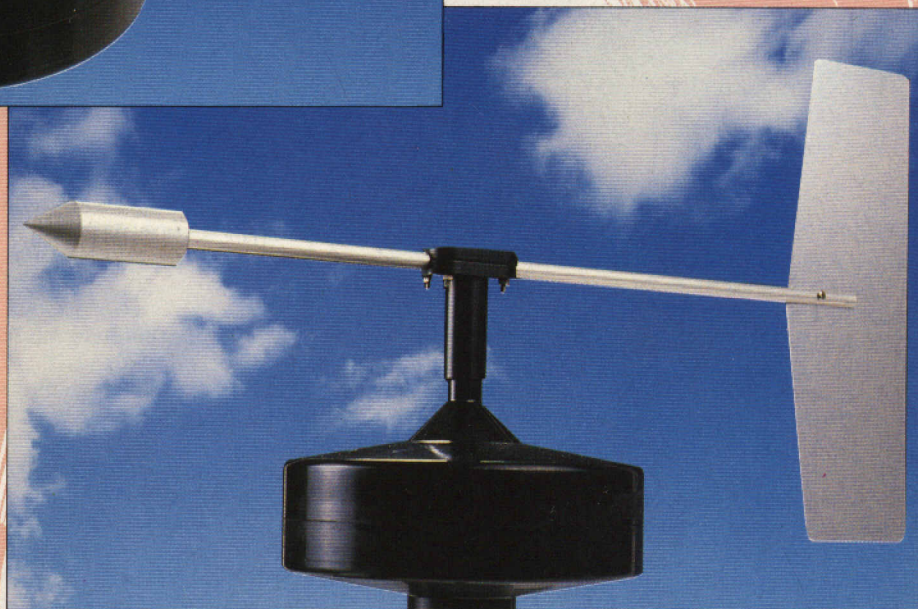

Photo 2. The wind direction 'arrow'.

from whence it came! In similar fashion to the wind speed sensor, the position of a coded disc is electronically sensed and translated into a 4 bit binary code. This system is capable of registering any one of sixteen points of the compass at 22.5 degrees resolution.

Circuit Description

The printed circuit board GD96E is used for both wind speed and wind direction projects, as is the code disc GD97F. All of the electronics shown in Figure 1 are utilised in the wind direction project, compared with the much reduced wind speed circuitry of Figure 2.

To simplify design, construction and (the ever important) cost, diffuse scan opto sensors SN1-5 are used to detect variations in reflected infrared field strength. In Figures 3 & 4 you can see that the sensor actually has both I/R emitter and phototransistor in a single package; objects placed in the field of view will either absorb or reflect infrared energy from the emitter which is then detected by the phototransistor. A black, non reflective, surface absorbs much of the infrared energy whilst a white surface will reflect it.

The code disc, shown in Figure 5, has

five rings printed in black and white sections, with the outside ring being a 'strobe' and the inner four rings coded in binary form. Sensors SN2-5 are placed around the PCB in such a way that a unique 4-bit binary code is produced for every 22.5 degrees rotation of the code disc. Although this type of arrangement allows for very easy construction it has drawbacks due to variations in device manufacture, disc surface reflectivity and extremely accurate alignment is required for each sensor. Unless all four sensors can be made to generate an output signal at the same time, then the codes produced will be incorrect. These problems are overcome by first squaring up the analogue waveform at the sensor output with schmitt trigger IC1 and then storing the

voltage level in a quad d-type latch IC2. As the disc rotates, sensors SN2-5 produce their voltage levels first and then a 'strobe' pulse, from SN1 (Figure 6) and the outer disc ring, latches data at the four output pins p7 to p10. The data remains stable here until the next 'strobe' pulse is produced from the disc being rotated again, thereby latching in the next set of data. Codes produced are in the usual binary form 0000 to 1111. The remaining IC1 inverter is not used on the wind direction project, but is used to shape analogue pulses connected to pin p5 from the wind speed PCB, pin p1 on Figure 2. Only SN1, R1 and C1 are used for this circuit (R2 is omitted and replaced by R9 on the wind direction PCB) and the +5V supply comes from the 5V regulator RG1 output, pin p2.

Constructing the Wind Speed Module

For general hints on module assembly, please refer to the constructors guide supplied with the kit. On this module only, most of the circuit board is not used and Figure 7 shows the few components required to complete this
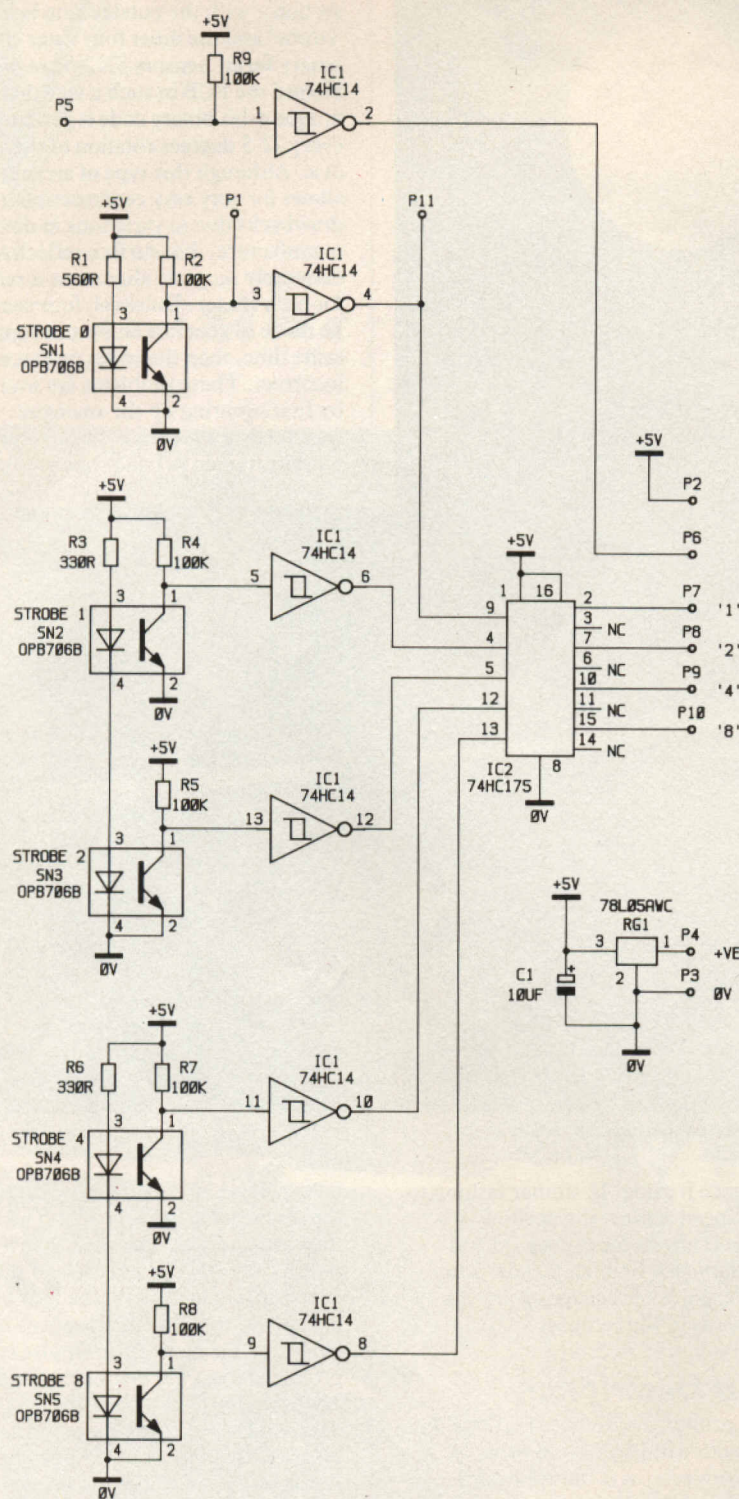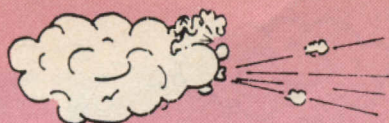
Figure 1. Wind direction circuit.

Figure 2. Wind speed circuit.

Please note that it is important to mount SN1 correctly if its operation is to be reliable! Solder all components in place and cut off the remaining wire ends, the finished module is shown in Photo 4.

Constructing the Wind Direction Module

Refer to Figure 9 for the PCB component layout and begin construction by inserting all eleven pins, p1 to p11. Unlike the previous module, fit all seven links onto the board and both IC sockets. Identify and fit nine resistors R1 to R9, capacitor C1 and regulator RG1; solder these in position and cut off the remaining
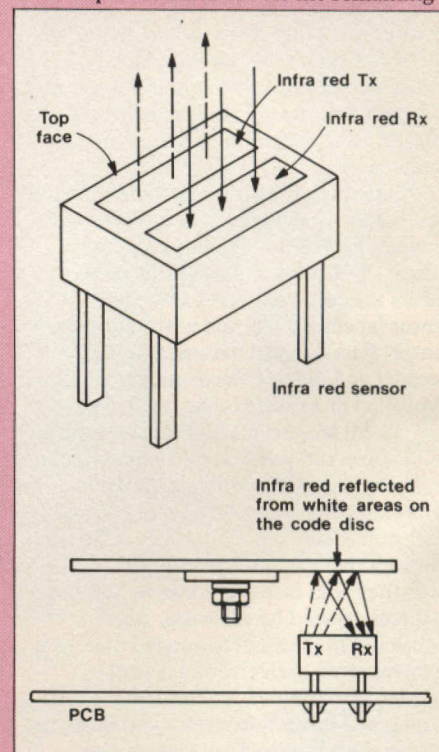
Figure 3. Sensor operation.

project. Fit the three links as shown, insert pins p1 to p3 and mount R1 and C1. Before inserting SN1, refer to Figure 4 and identify the short cathode (k) lead 4; position the sensor so that the cathode (k) lead enters into a PCB hole also marked with a 'k' and solder one of the leads onto the board. Adjust the sensor until it is standing square and 9mm above the board, as shown in Figure 8 and Photo 3 - if the sensor is standing too high, such as the rear one of the two shown in the photograph, then it will foul the code disc! Solder the remaining three leads in place.
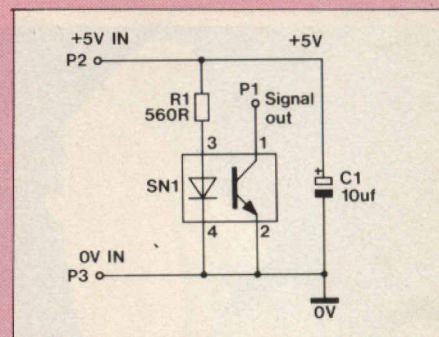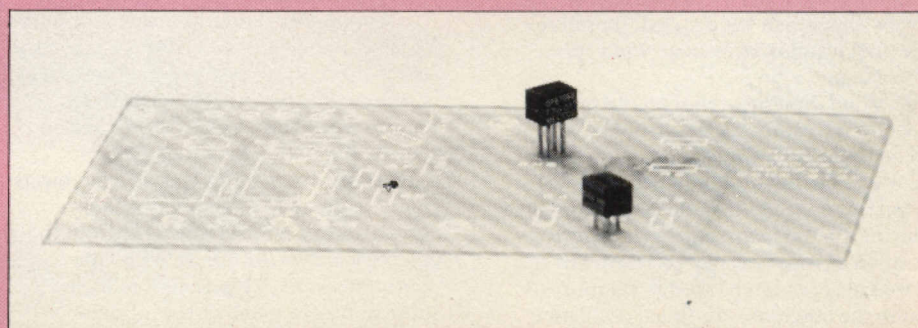

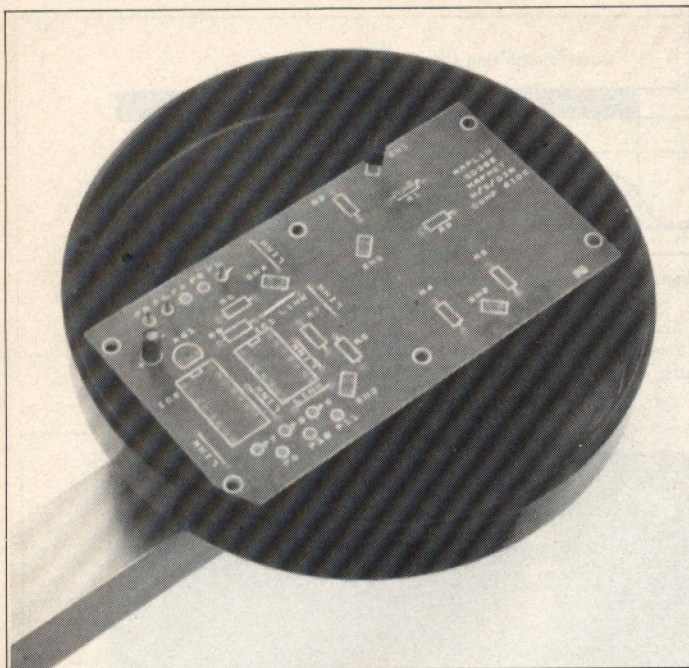Photo 3. Mounting sensors on the pcb.
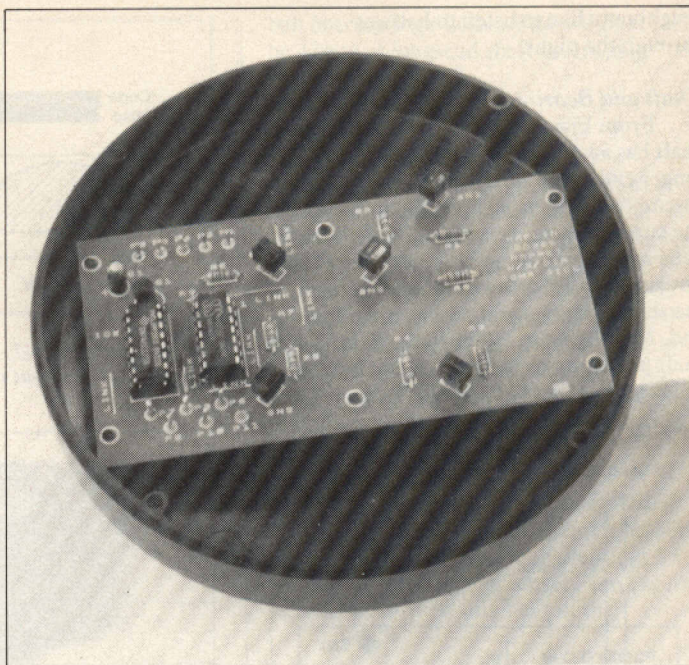
Photo 4. Completed wind speed pcb.

Photo 5. Completed wind direction pcb.

wire ends. Insert IC's 1 & 2 into their sockets and mount all five sensors, SN1 to SN5, taking note of the precautions as stated on the wind speed module. The finished module is shown in Photo 5.

General Details

Basically, the two sensor housings are identical, see Figure 10, except for the external cup and vane fittings. The sensor housings are fitted onto each end of a mounting bar and the assembly is clamped onto a suitable mast (not supplied in the kit).

Mounting Studs

Cut two 45mm lengths from the 2BA studding as shown in Figure 11, fit a 2BA nut onto one end, remove any grease and oxidation present with abrasive cloth and solder the nut to the stud. You require one of these for each sensor housing. Once the stud has cooled down, insert it into the centre mounting position of a bottom housing, from the inside first. The screw head should fit into the hexagonal moulding and you may need to file away some of the solder in order to achieve this.

Housing Assembly

At each end of the support mounting bar there are three holes. Position a bottom housing, with its protruding 2BA stud inserted into the centre hole, so that the locating spigot then fits into the outside hole, see Figure 12. The remaining holes should now align with each other and this is where the connecting cables will be fitted. Now fit the 2BA shake washer and nut, shown in Figure 13 & Photo 6, and tighten carefully to avoid cracking the plastic or distorting the bar. The end caps are fitted later - after wiring up - and they prevent water from entering. Equally important, the caps stop wind from blowing through the tube and emitting a noise like a steam train - just what your
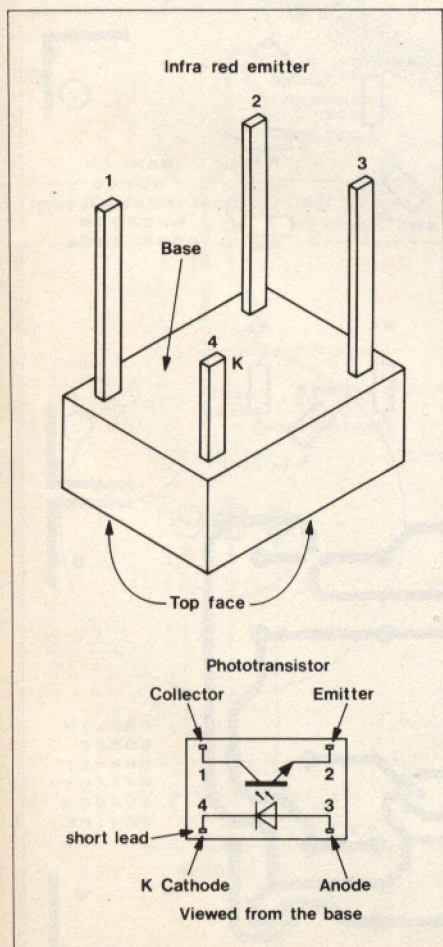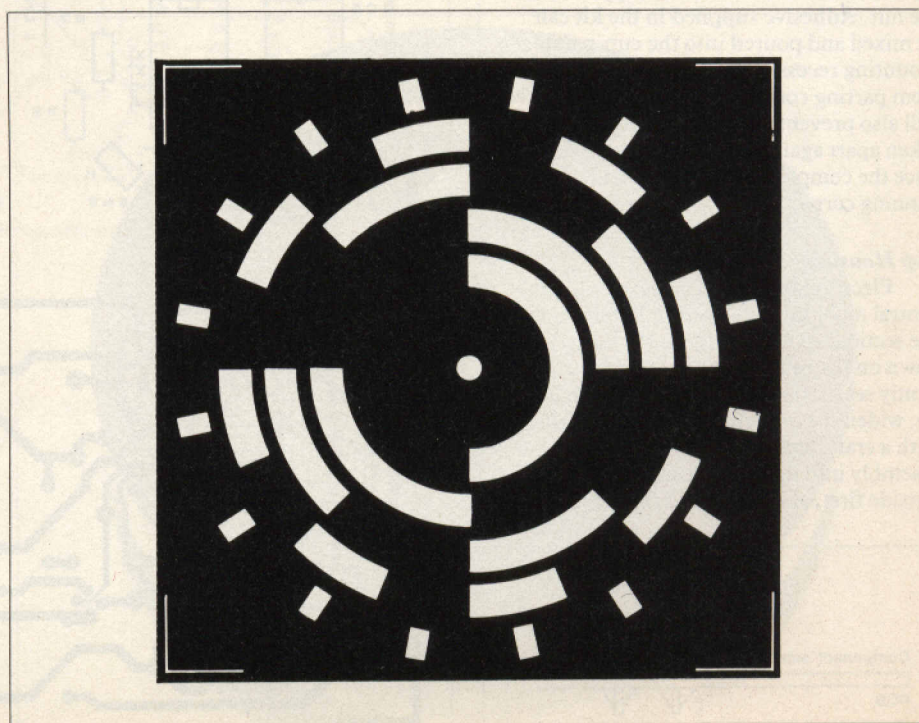

Figure 4. The OPB706B sensor.

Figure 5. Code disc.

neighbours like to listen to halfway through the night!

Shaft and Bearings

From Figure 14 you can see that the shaft has a long and a short end. The longer end takes the code disc mounting assembly and the short end fits into either the cup mounting assembly or the weather vane mounting assembly. Place one of the miniature ball races over the short end of the shaft as shown and push it up to the end. Now fit a cup mounting or pointer shaft mounting over the shaft and bearing, see Figures 15 and 16, and lock the
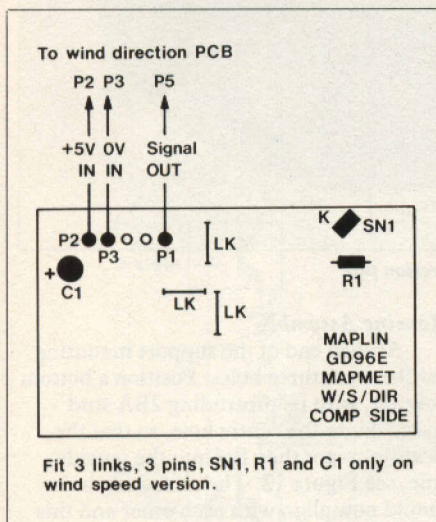
Figure 7. Wind speed component layout.

assembly together with an M3 shake washer and nut. You will need a pair of long nose pliers for this fiddly job! Tighten the nut as much as possible and check that the ball bearing can still be freely turned. If you can turn the mounting whilst holding the shaft still, then the nut needs further tightening, but do NOT over-tighten as the thread will be stripped from the nut. Adhesive supplied in the kit can be mixed and poured into the cup/pointer mounting recess and will prevent the nut from parting company with the shaft; it will also prevent the assembly from being taken apart again, therefore only do this once the complete system is up and running correctly!

Top Housing

Place the remaining bearing onto the central moulding as shown in Photo 7 and the sectioned view of Figure 10. Push down on the bearing until its flange is firmly seated onto the plastic; if it will not go, widen the hole entrance very slightly with a craft knife. Now insert the shaft assembly into the top housing, from the outside first, and push until the outside
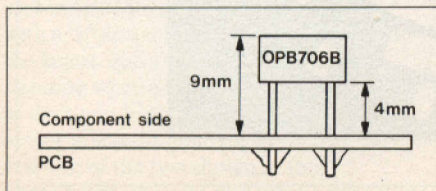
Figure 8. Mounting sensors onto pcb.
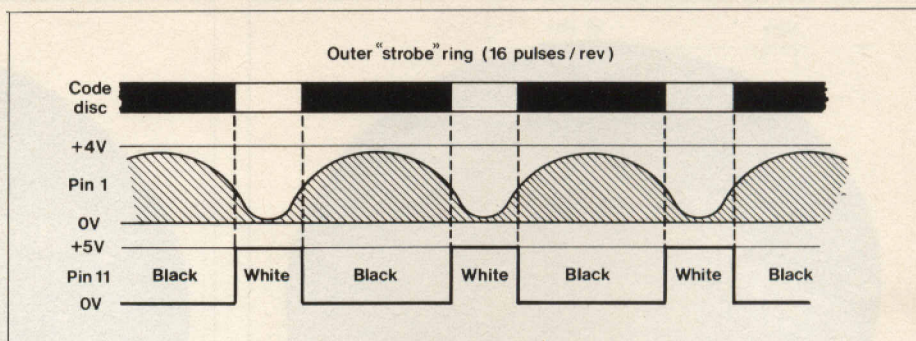
Figure 6. SN1 output signals.
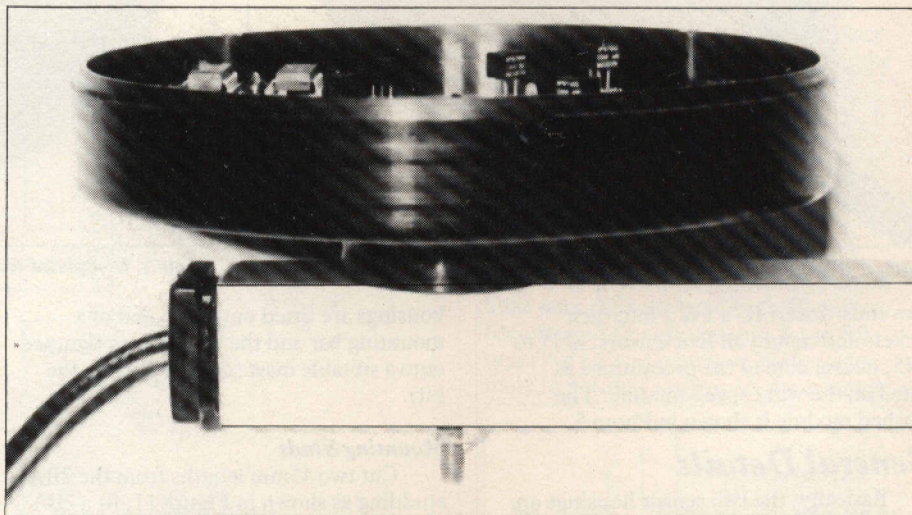
Photo 6. Mounting a bottom housing onto the support bar.
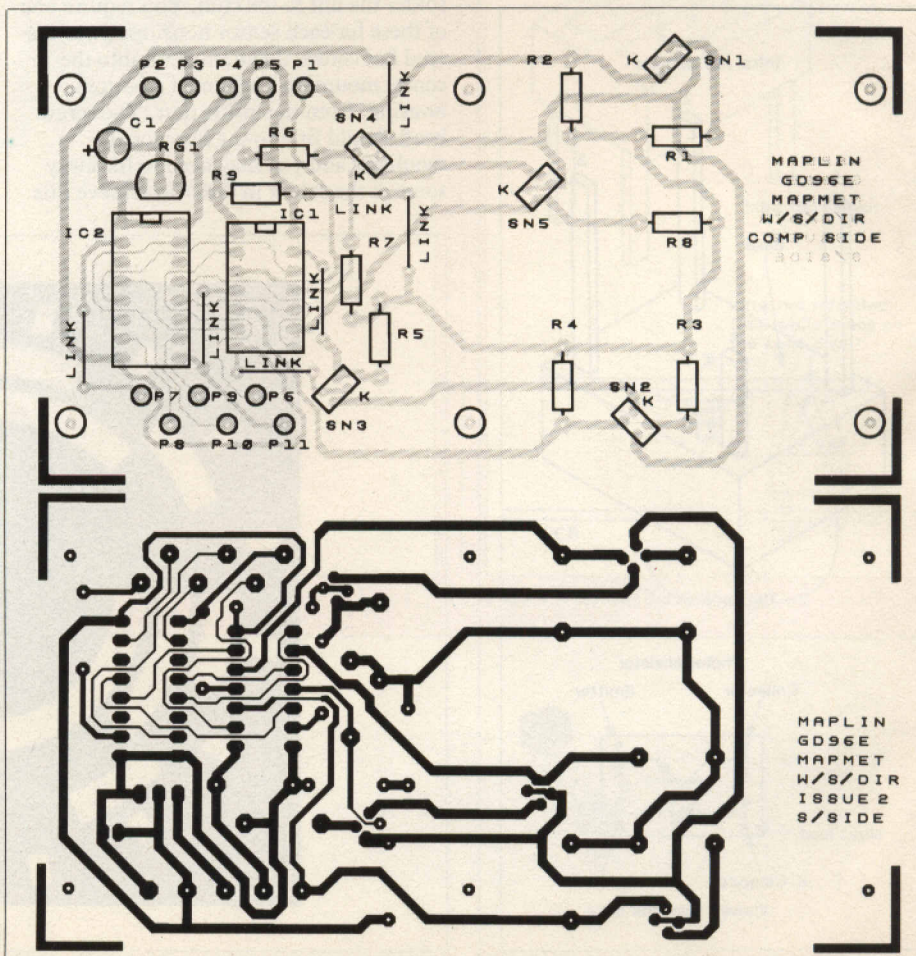
Figure 9. Track and layout of the pcb.
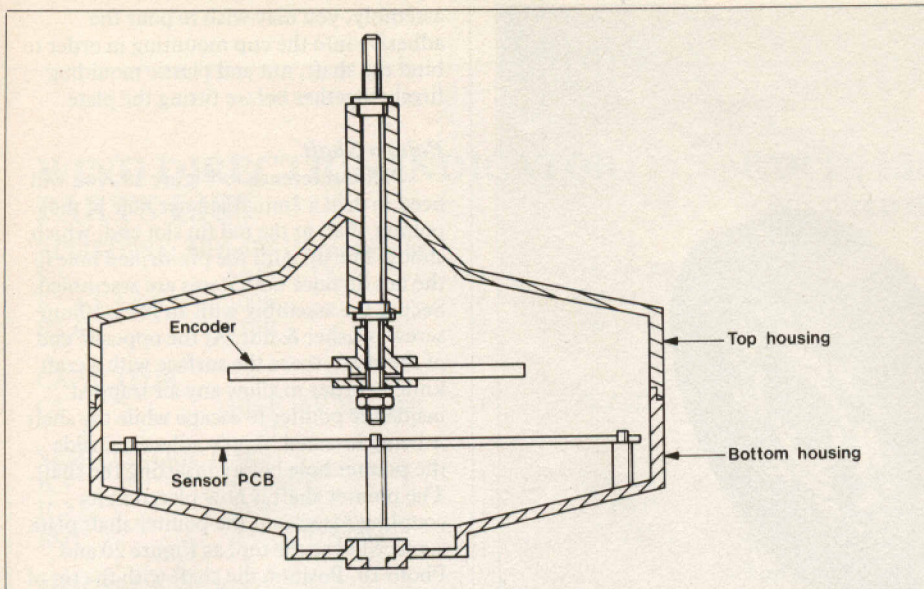
Figure 10. *General sensor head layout.*

ball bearing pops home. There should now be 22mm of long-end shaft protruding through to the inside.

Code Disc

Identify the encoder coupler moulding and place it over the shaft as in Figure 17, place the code disc onto the coupler with the printed surface facing you - see Photo 8 - and press fit both items together. Fit the coupler plate and an M3 shake washer and nut to lock the assembly together. To prevent the nut loosening up when in use, a small blob of adhesive can be put onto the end of the shaft before final assembly.

Wind Speed Cups

Three cups, see Figure 18, are fitted into the cup mounting and they are held in place with the cup mounting plate and 3 x No.4 x 3/8″ self tapping screws. See Figure 15 and Photo 9. At this stage of the
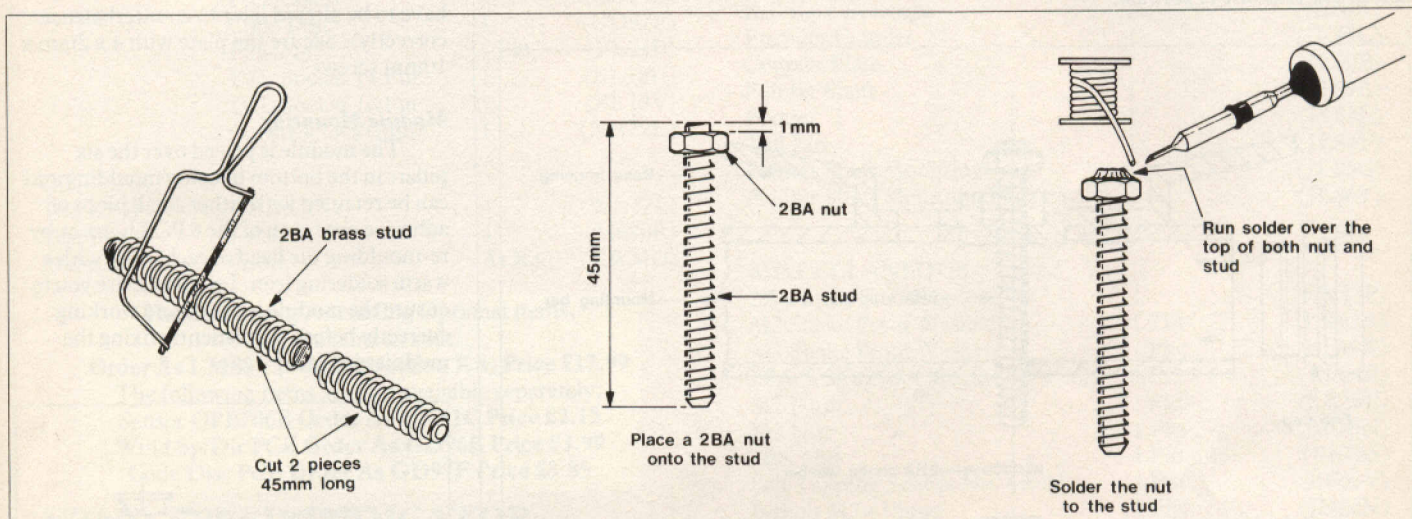
Figure 11. *Making the fixing studs.*
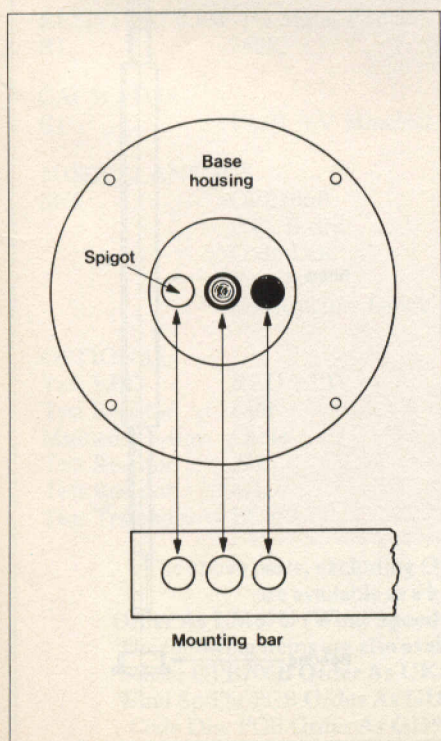
Figure 12. *Locating the sensor head on the bar.*
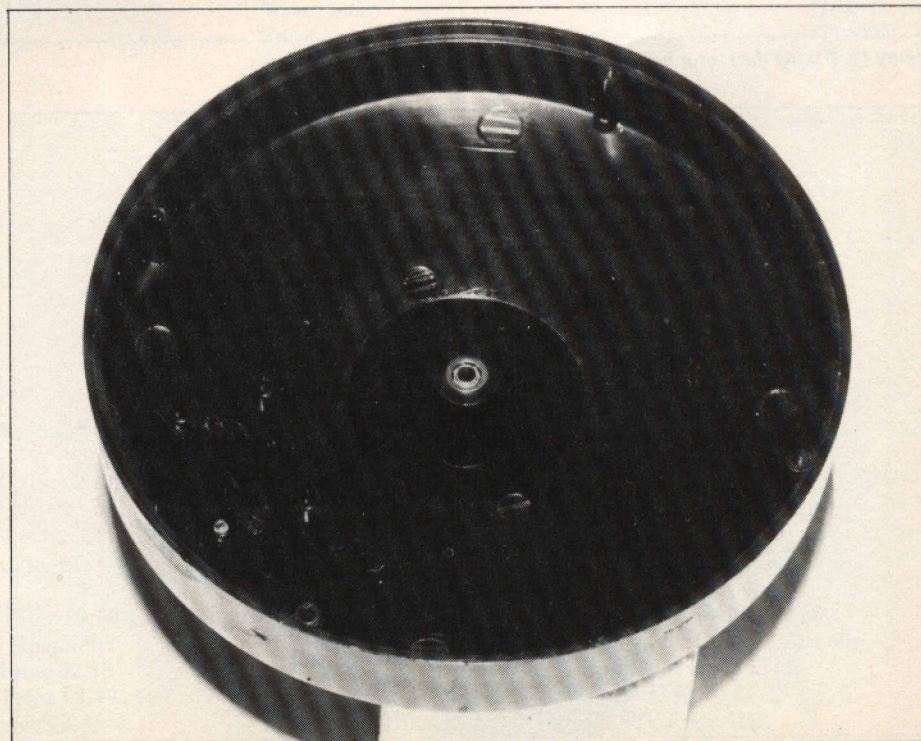
Photo 7. *The ball race in position.*
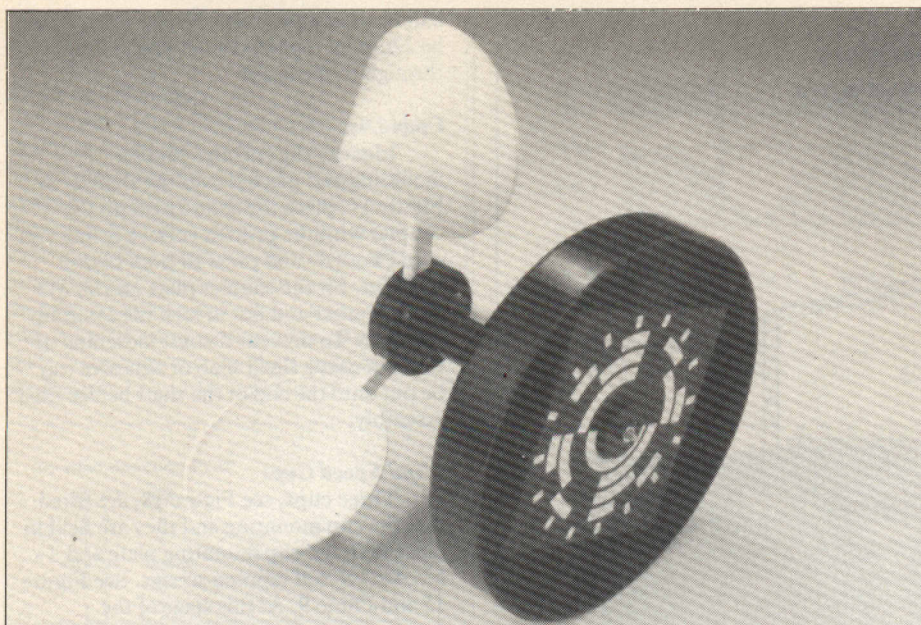
Photo 8. The code disc in position.
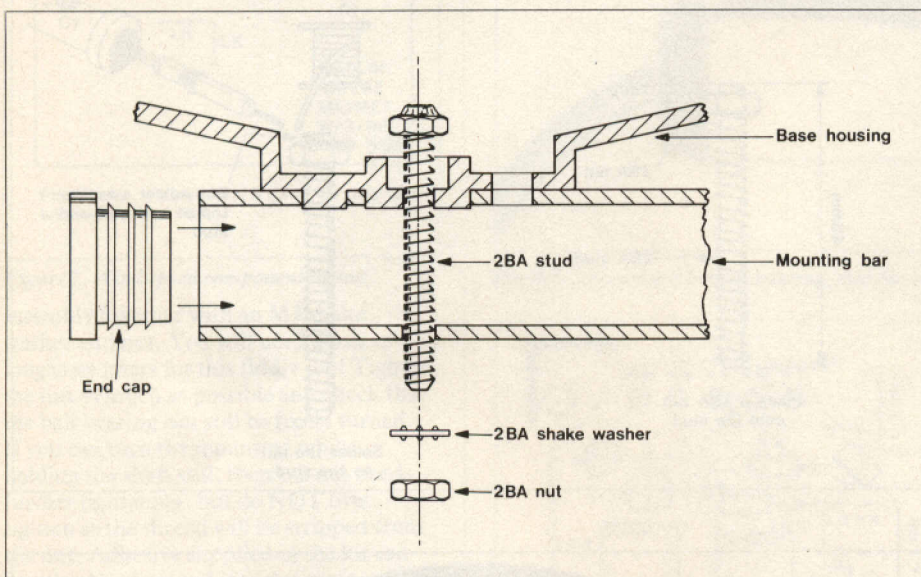
Figure 13. Fixing the sensor head to the bar.

Labels in Figure 13: Base housing, 2BA stud, Mounting bar, End cap, 2BA shake washer, 2BA nut
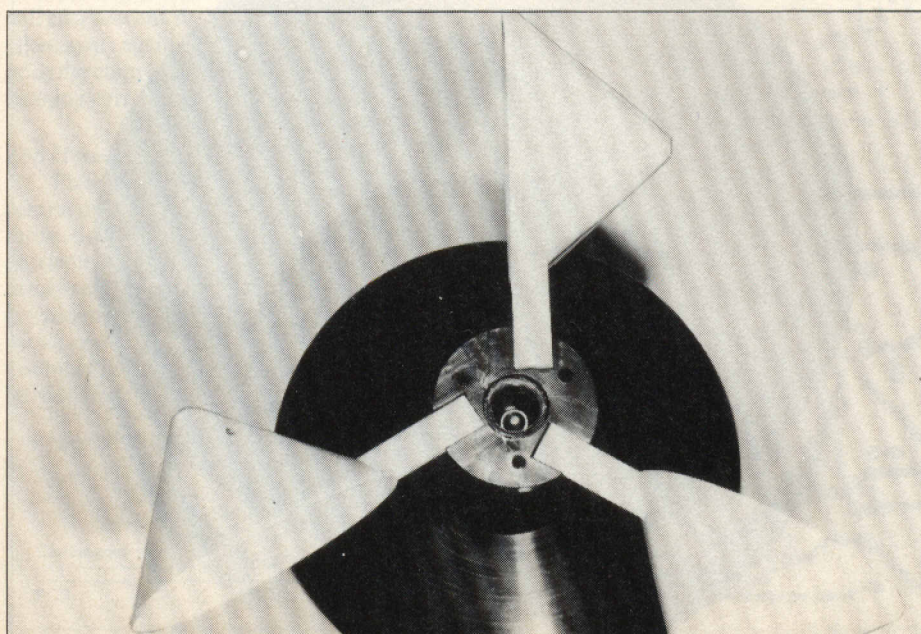
Photo 9. Fixing the wind speed cups.

assembly, you may wish to pour the adhesive into the cup mounting in order to bind the shaft, nut and plastic moulding firmly together before fitting the plate.

Pointer Shaft

With reference to Figure 19, you will need to drill a 2mm diameter hole in the pointer shaft at the tail fin slot end, which should line up with the pre-drilled hole in the tail fin once both items are assembled. Secure the assembly with an M2 x 10mm screw, washer & nut. At the opposite end of the shaft, score the surface with a craft knife in order to allow any air trapped inside the pointer to escape while the shaft is being inserted. Apply adhesive inside the pointer hole before inserting the shaft. The pointer shaft is now placed in its coupling recess and the pointer shaft plate is placed over the top, as Figure 20 and Photo 10. Position the shaft with the tip of the pointer set approximately 180mm from the centre of the plate (this distance may have to be altered later to counterbalance correctly). Secure the plate with 4 x 2mm x 10mm screws.

Module Mounting

The module is placed over the six pillars in the bottom housing moulding and can be retained with either small blobs of adhesive over each of the 6 PCB holes or by re-moulding the head of each pillar with a warm soldering iron. I would advise you to ensure the module is tested and working correctly before permanently fixing the modules in place!

Figure 14. The axle shaft.

Labels in Figure 14: Bearing, Shaft, Bearing
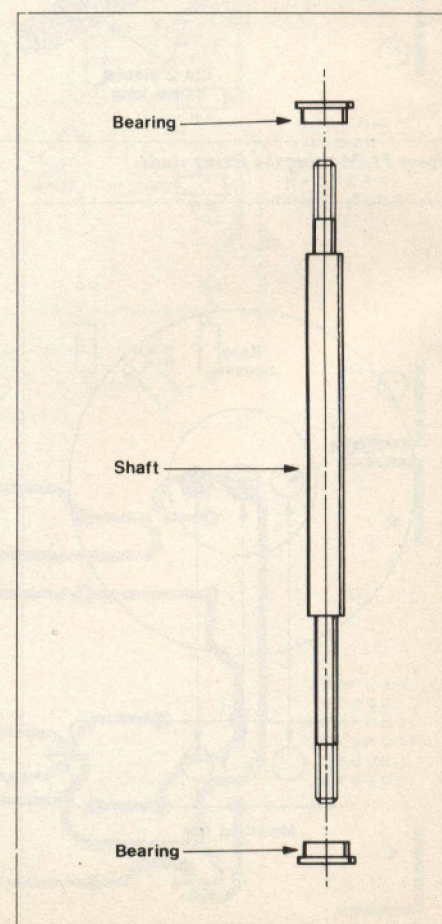
WIND DIRECTION INDICATOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	560R	1	(M560R)
R2,4,5,7,8,9	100k	6	(M100K)
R3,6	330R	2	(M330R)

CAPACITOR

C1	10μF 16V Minelect	1	(YY34M)

SEMICONDUCTORS

IC1	40106BE	1	(QW64U)
IC2	74HC175	1	(UB45Y)
RG1	μA78L05AWC	1	(QL26D)

MISCELLANEOUS

SN1-5	OPB706B	5	(UK81C)
	P.C. Board	1	(GD96E)
	Code Disc	1	(GD97F)
	Pins 2145	1 Pkt	(FL24B)
	DIL Socket 14 Pin	1	(BL18U)
	DIL Socket 16 Pin	1	(BL19V)
	Constructors Guide	1	(XH79L)

OPTIONAL

Test LED	RED LED	4	(WL27E)
Test Resistor	680R	4	(M680R)
Multicore 6-way	Cable	As Req	(XR26D)

The above parts, excluding Optional items, are available as a kit:
Order As LM88V (Wind Direction Kit) Price £17.99
The following items are also available separately:
Sensor OPB706B **Order As UK81C Price £2.15**
Wind Sp/Dir PCB **Order As GD96E Price £3.99**
Code Disc PCB **Order As GD97F Price £3.85**

WIND SPEED INDICATOR PARTS LIST

RESISTOR: 0.6W 1% Metal Film

R1	560R	1	(M560R)

CAPACITOR

C1	10μF 16V Minelect	1	(YY34M)

MISCELLANEOUS

SN1	OPB706B	1	(UK81C)
	P.C. Board	1	(GD96E)
	Code Disc	1	(GD97F)
	Pins 2145	1 Pkt	(FL24B)
	Constructors Guide	1	(XH79L)

OPTIONAL

Test LED	RED LED	1	(WL27E)
Test Resistor	680R	1	(M680R)
Multicore 6-way	Cable	As Req	(XR26D)
Test Resistor	22k	1	(M22K)
Test Resistor	47k	1	(M47K)
Test Transistor	BC557	1	(QQ16S)

The above parts, excluding Optional items, are available as a kit:
Order As LM87U (Wind Speed Kit) Price £9.99
The following items are also available separately:
Sensor OPB706B **Order As UK81C Price £2.15**
Wind Sp/Dir PCB **Order As GD96E Price £3.99**
Code Disc PCB **Order As GD97F Price £3.85**

PARTS LIST

WIND SPEED HARDWARE

Top Housing	1	(YT67X)
Bottom Housing	1	(YT68Y)
Shaft	1	(JL77J)
Ball Race Bearings	2	(JL78K)
Encoder Coupler	1	(JL79L)
Coupler Plate	1	(JL80B)
Wind Cups	3	(YT71N)
Cup Mounting	1	(JL81C)
Cup Mounting Plate	1	(JL82D)

WIND DIRECTION HARDWARE

Top Housing	1	(YT67X)
Bottom Housing	1	(YT68Y)
Shaft	1	(JL77J)
Ball Race Bearings	2	(JL78K)
Encoder Coupler	1	(JL79L)
Coupler Plate	1	(JL80B)
Pointer Shaft	1	(YT69A)
Pointer	1	(JL83E)
Tail Fin	1	(JL84F)
Pointer Shaft Mounting	1	(JL85G)
Pointer Shaft Mounting Plate	1	(JL86T)

MISCELLANEOUS

2BA Brass Studding	1	(FW13P)
M2 Shake Proof Washer	1 Pkt	(LR61R)
M3 Shake Proof Washer	1 Pkt	(BF44X)
2BA Shake Proof Washer	1 Pkt	(BF24B)
M2 Nut	1 Pkt	(LR59P)
M3 Nut	1 Pkt	(BF58N)
2BA Nut	1 Pkt	(BF16S)
Self Tapping Screws No. 4×⅜"	1 Pkt	(BF65V)
Isobolt M2×10mm	1 Pkt	(JD12N)
Isobolt M2×6mm	1 Pkt	(JD11M)
Mounting Bar	1	(YT70M)
Mast Clamp	1	(JL87U)
End Cap	2	(JL88V)
Bubble Pack Adhesive	2	(FL45Y)

The above items are available as a kit:
Order as LM90X (Wind Hardware Kit) Price £29.95.

The following items are also available separately:

Top Housing **Order As YT67X Price 80p**
Bottom Housing **Order As YT68Y Price 80p**
Shaft **Order As JL77J Price £1.80**
Ball Race Bearings **Order As JL78K Price £3.45**
Encoder Coupler **Order As JL79L Price 60p**
Coupler Plate **Order As JL80B Price 60p**
Wind Cups **Order As YT71N Price 50p**
Cup Mounting **Order As JL81C Price 60p**
Cup Mounting Plate **Order As JL82D Price 45p**
Pointer Shaft **Order As YT69A Price 95p**
Pointer **Order As JL83E Price £2.50**
Tail Fin **Order As JL84F Price £1.45**
Pointer Shaft Mounting **Order As JL85G Price 60p**
Pointer Shaft Mounting Plate **Order As JL86T Price 60p**
Mounting Bar **Order As YT70M Price £3.45**
Mast Clamp **Order As JL87U Price £1.25**
End Cap **Order AS JL88V Price 18p**
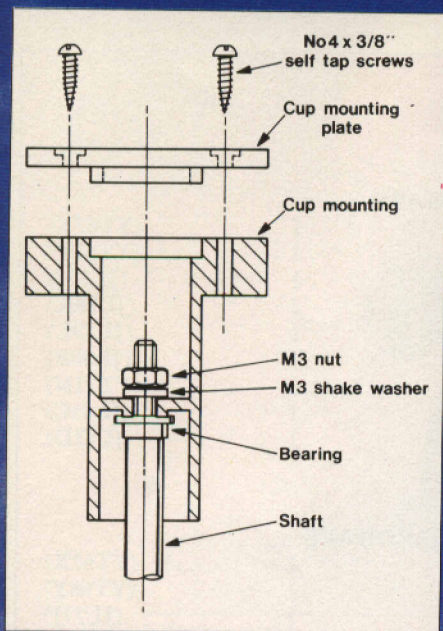
Figure 15. Fixing the cup mounting to the shaft.

Figure 16. Fixing the pointer mounting to the shaft.
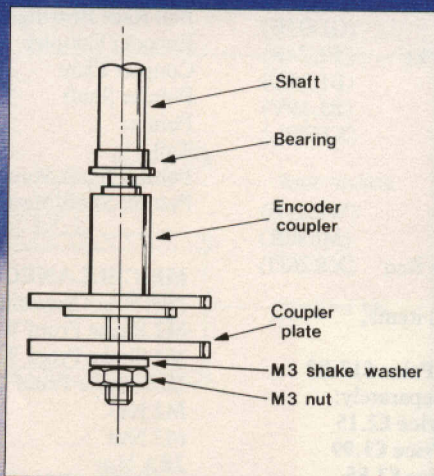
Figure 17. Fixing the code disc in position.
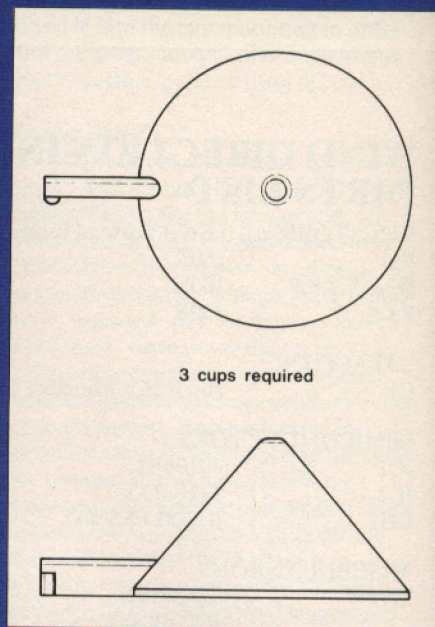
Figure 18. The wind speed cups.

Testing the Modules

Module operation can be tested, as a temporary measure, by connecting up LED's, shown in Figure 21; module outputs would normally be connected to the main decoder board which will be appearing in a later issue. A 12VDC 100mA supply is required and is wired with +V to pin p4 and -V to pin p3 on the wind direction PCB. I suggest that hook-up wire is connected for testing purposes only, through the support bar to the two sensor heads, thus allowing components to be wired up externally. Pin p2 (+5V) on the wind speed PCB can be wired directly to pin p2 on the wind direction PCB and this also applies to the 0V pin p3. After wiring, clip each module onto the mounting pillars and fit the top housings in place. Turn on the power supply and revolve the pointer shaft slowly in an anti-clockwise direction, whereupon the four LED's should flash on and off. Position the pointer shaft such that all LED's are extinguished and continue to turn the shaft until the first LED to light up corresponds to pin p7, or binary 0001, the next LED only to light up should then correspond to pin p8, or binary 0010. All 16 codes should be individually generated in sequence as the shaft is revolved with pin p7 as the least significant digit and p10 as the most significant.
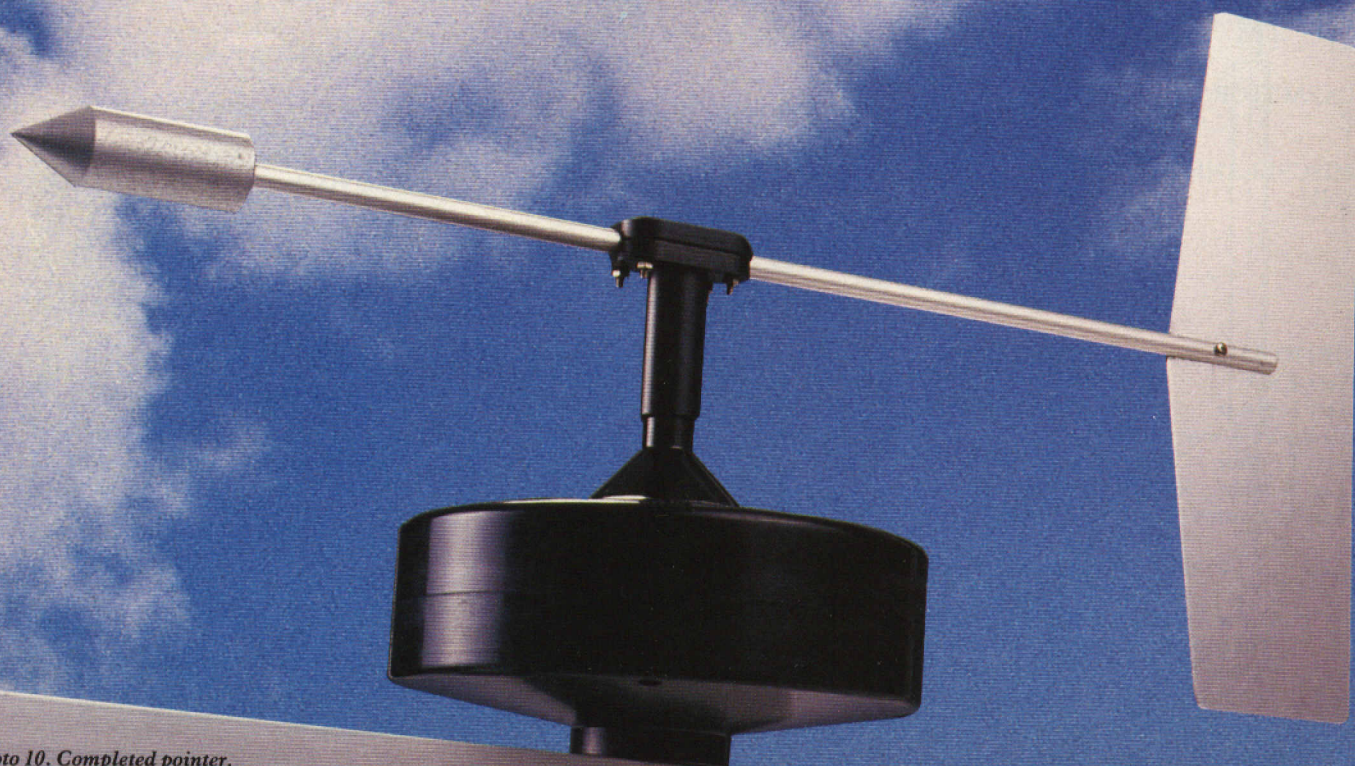
Photo 10. Completed pointer.
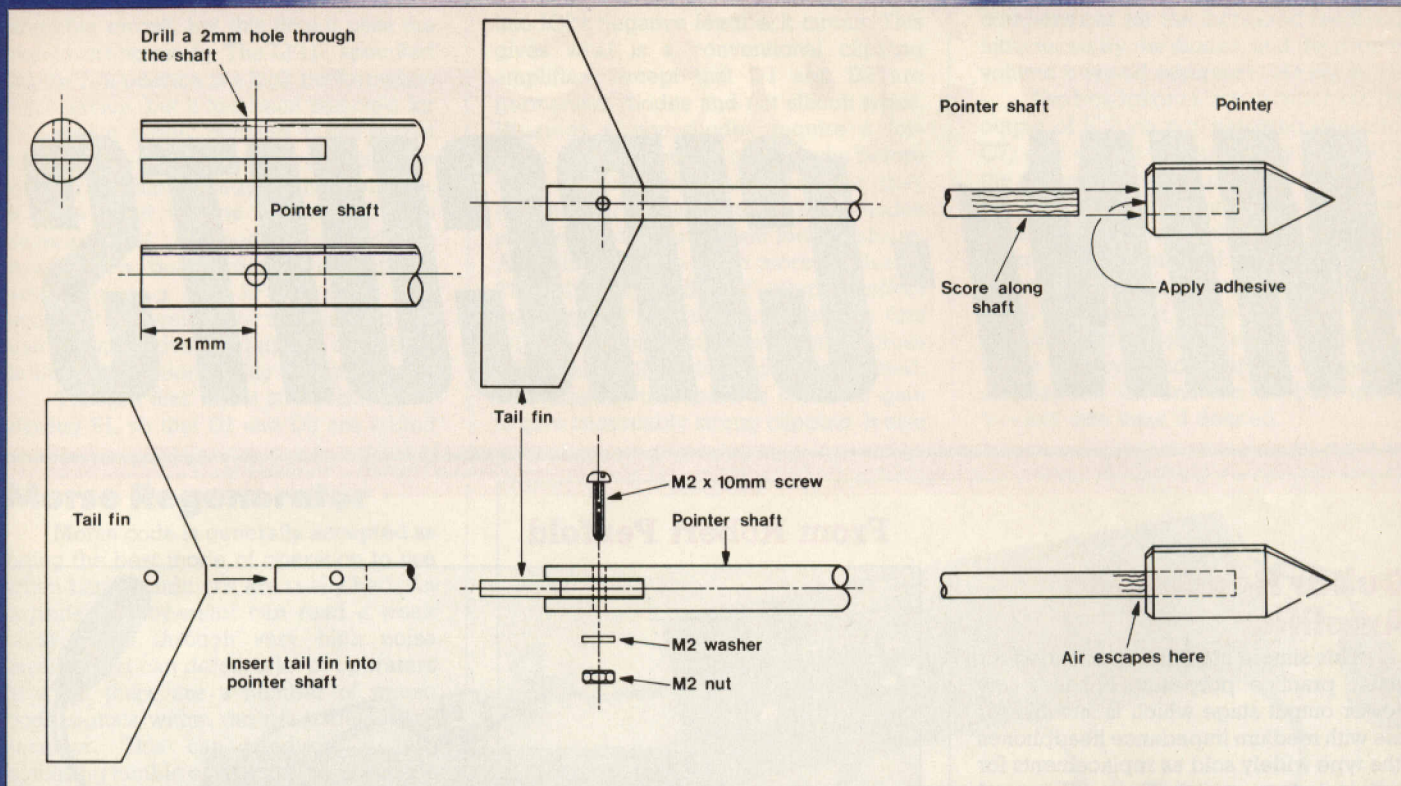
Figure 19. Assembling the pointer.

If the LED's do not light up, check for +5V out from pin p2 and that the test LED's are wired correctly.

Any code that is repeated or out of sequence relates to 1 or more of the I/R sensors SN1-5 being out of alignment. SN1 is easily checked by monitoring the voltage variations from pin p11 with a meter (or 'scope) and SN2-5 collectors (pin 1) can be similarly checked to the levels and waveforms in Figure 6. As a guide, the six IC1 outputs (pins 2, 4, 6, 12, 10, and 8) are normally low (0V) which corresponds to the sensor phototransistors being turned off; ambient lighting will affect this situation, therefore monitor these voltage levels in subdued lighting conditions! If a piece of white paper or card is placed onto the sensor, then the phototransistor turns on and the related IC1 output goes high (+5V); when the paper is lifted 8/10mm above the sensor, the IC1 output will go low again. For testing the wind speed

module, connect the BC557 transistor switch as shown in Figure 21(a) or wire the pin p1 sensor output to the wind direction module input pin p5 and a 680R resistor and test LED between +5V (pin p2) and pin p6 on this module. Spin the wind speed cups and the test LED should flash on and off 16 times per revolution. Again, it may be necessary to re-position SN1 slightly if the LED does not pulse, as discussed previously.

Final Assembly

The top housing can be fitted onto the bottom housing and the assembly held together either with silicon rubber or PVC insulating tape placed over the join around the outside. There are four screw holes in the bottom housing designed to take 25/30mm long, 2.5mm diameter screws (not supplied in the kit) and these can also be used if required.
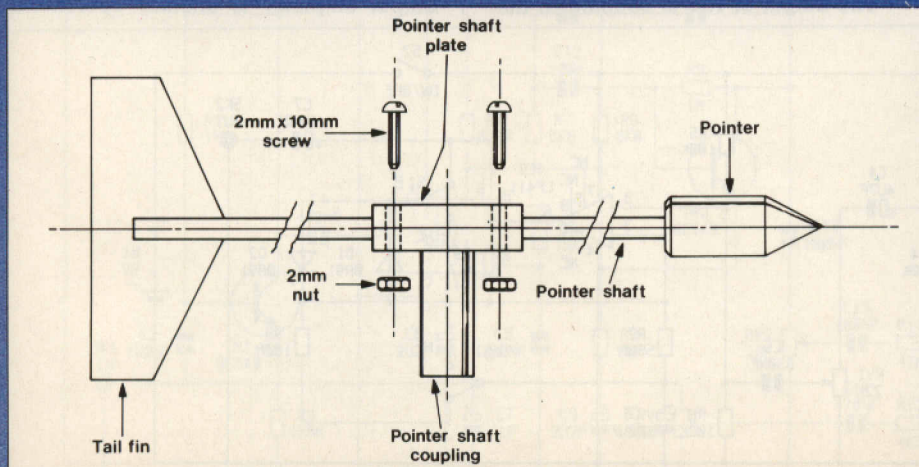
Figure 20. Fixing the pointer in position.
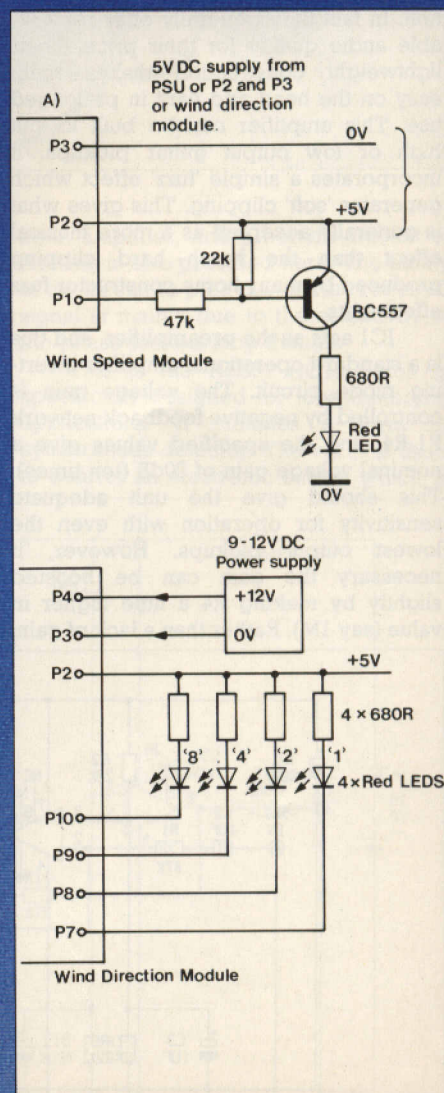
Figure 21. Test circuits.

Bob's MINI-CIRCUITS

From Robert Penfold

Guitar Headphone Amplifier

This simple amplifier is intended for guitar practice purposes. It has a low power output stage which is suitable for use with medium impedance headphones (the type widely sold as replacements for personal stereo units). These offer good efficiency, but mostly have a wide frequency response and quite low distortion. In fact they generally offer remarkable audio quality for their price. Their lightweight construction makes them easy on the head and ears in prolonged use. This amplifier can be built to suit high or low output guitar pickups. It incorporates a simple 'fuzz' effect which generates 'soft' clipping. This gives what is generally accepted as a more musical effect than the harsh hard clipping produced by many home constructor fuzz effect units.

IC1 acts as the preamplifier, and this is a standard operational amplifier inverting mode circuit. The voltage gain is controlled by negative feedback network R1-R4, and the specified values give a nominal voltage gain of 20dB (ten times). This should give the unit adequate sensitivity for operation with even the lowest output pickups. However, if necessary the gain can be boosted slightly by making R4 a little higher in value (say 1M). Rather than a lack of gain,
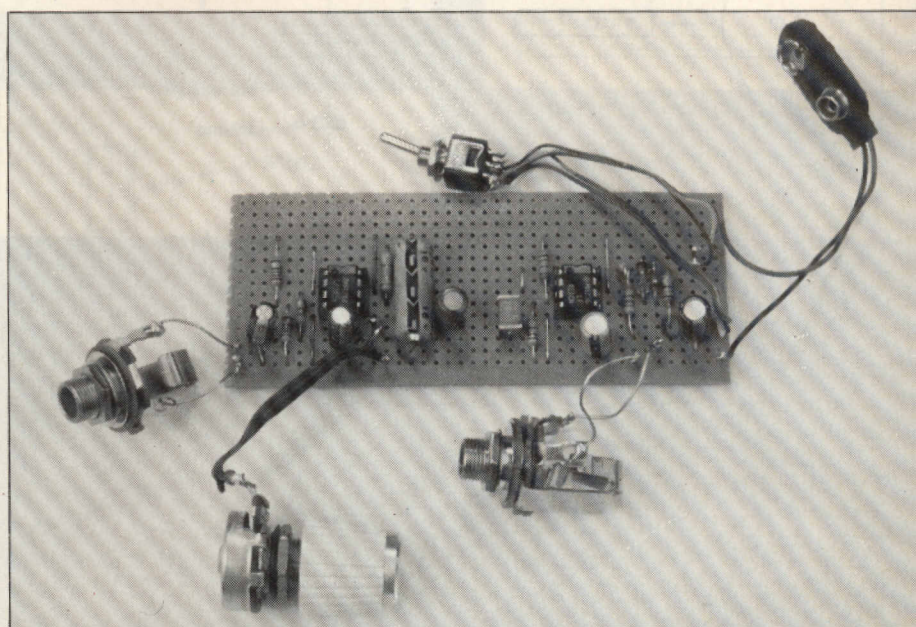
Guitar Headphone Amplifier.

it is more likely that the unit will prove to be too sensitive if it is used with a modern pickup having a high output level. There is then a risk of IC1 being driven into clipping and producing severe distortion. In order to avoid this, if the unit is to be used with high output pickups the value of R4 should be reduced to 47k. IC1 then merely acts as a unity gain buffer stage.

The output of IC1 is coupled to the

volume control by C4. Most electric guitars have a built-in volume control, but in order to obtain optimum noise performance the guitar's volume control should be set at maximum and the volume should be controlled using RV1. The unit does not include any tone controls, but this is not too important as they are also a feature of most electric guitars. The output amplifier is another operational
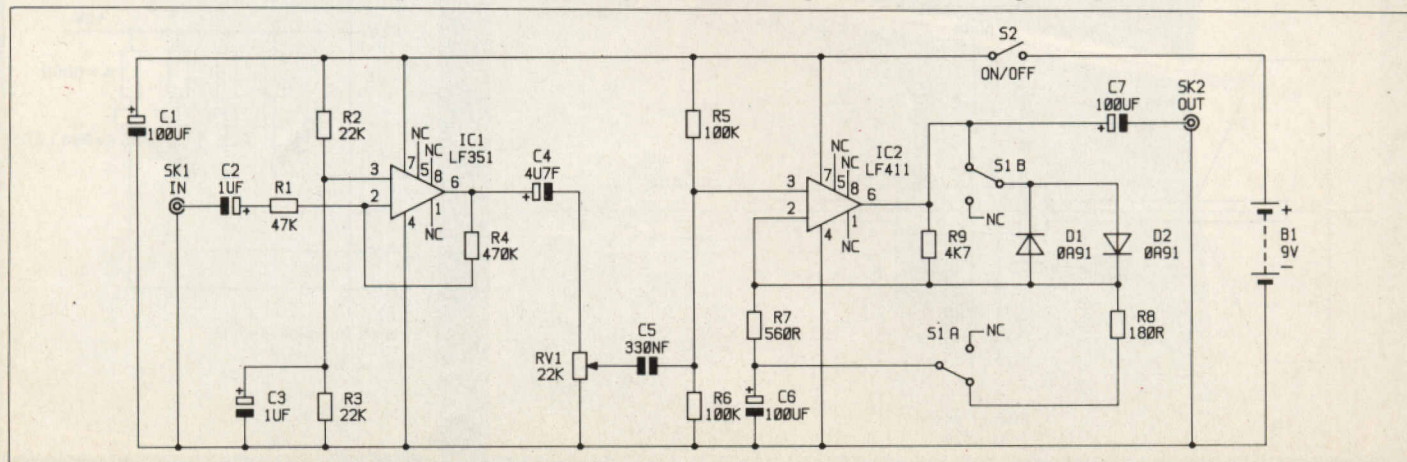
Guitar Headphone Amplifier Circuit.

amplifier circuit, but this time it uses the non-inverting mode. The LF411 specified for the IC2 position is a high performance bifet device, but it has been selected for this circuit simply because it has output characteristics that seem well suited to driving medium impedance headphones. It gave good volume when tried with several pairs of medium impedance headphones, but some other operational amplifiers (e.g. the LF351) were less successful. I would not recommend the use of alternative operational amplifiers in the IC2 position of this circuit.

The 'soft fuzz' effect is introduced by closing S1, so that D1 and D2 are added into IC2's negative feedback circuit. This gives what is a conventional clipping amplifier, except that D1 and D2 are germanium diodes and not silicon types. Whereas silicon diodes require a forward bias of about 0.6 to 0.65 volts before they will conduct, and thereafter they conduct very heavily, germanium diodes start to conduct at a much lower voltage. Also, they turn on much more gradually. This gives a good 'soft' clipping effect and a good 'fuzz' sound. When the fuzz effect is switched in, R8 is shunted across R7 so that IC2's voltage gain is boosted. This ensures that there is sufficient gain to give reasonably strong clipping. It also compensates for the increased feedback introduced by the diodes, and the drop in volume it would otherwise introduce.

The headphones are driven from the output of IC2 via d.c. blocking capacitor C7, and results will probably be best if the phones are wired in series (i.e. ignore the earth tag and connect the other two tags to the output of the amplifier). The current consumption of the circuit is only about 5 milliamps under quiescent conditions, and two or three milliamps more than this at high volume levels. A PP3 size 9 volt battery is adequate as the power source, and the unit can be built into a 'pocket' size case if desired.

Morse Regenerator

Morse code is generally accepted as being the best mode of operation to use when band conditions are really bad. An experienced operator can read a weak code signal through very high noise levels. What can defeat a lot of operators is when there are a number of morse code signals within the passband of the receiver. This can produce a very confusing jumble of tones. A lot of people use some form of automatic morse decoder these days, and these are often not very good at sorting out the required morse code signal from the noise, or from adjacent channel interference.

Some receivers overcome these problems by having highly selective i.f. filters for c.w. reception, or a narrow bandwidth audio filter. However, these features are absent from many short wave sets. It is not too difficult to add an 'out-board' audio filter, or to use the interesting alternative of a tone regeneration unit. The basic idea of a regenerator is to have an audio oscillator which is keyed on and off by the received c.w. signal. Although the audio input signal may be heavily infested with noise, the regenerated output signal is the output from the keyed oscillator, and is totally free of noise.
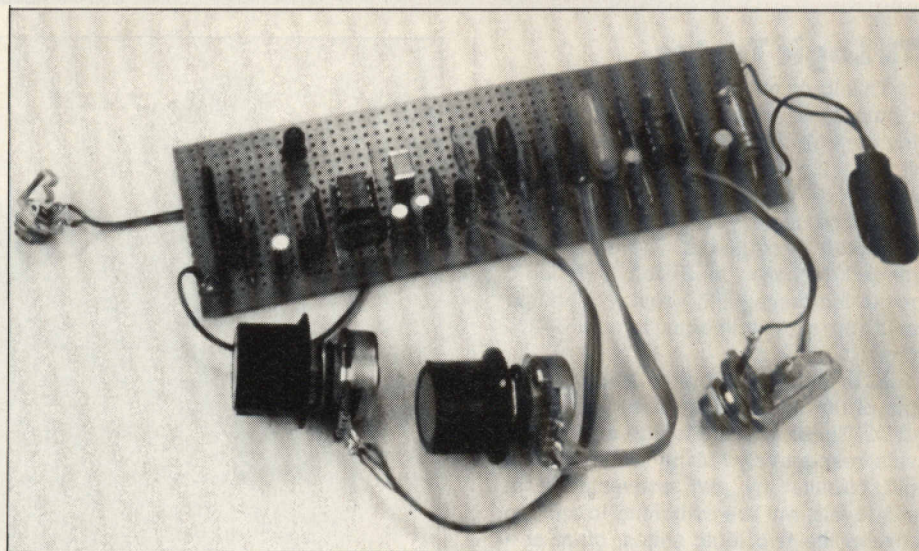
Morse Regenerator.

Units of this type can be based on a filter plus rectifier and smoothing circuit, or a phase locked loop. It is the latter that forms the basis of this circuit. The input signal is taken from the tape recorder output of the receiver, or the headphone socket if no recorder output is available. If using the headphone socket, be careful not to advance the volume control so far as to overload the unit. TR1 acts as an input amplifier, and a certain amount of filtering is also provided here. The ability of the circuit to pick out just the required signal is mainly due to the selectivity of the phase locked loop though.

This is the NE567 (IC1) which is specifically designed for tone decoding applications. It includes a form of synchronous detector. The v.c.o. is used to control an electronic switch which is
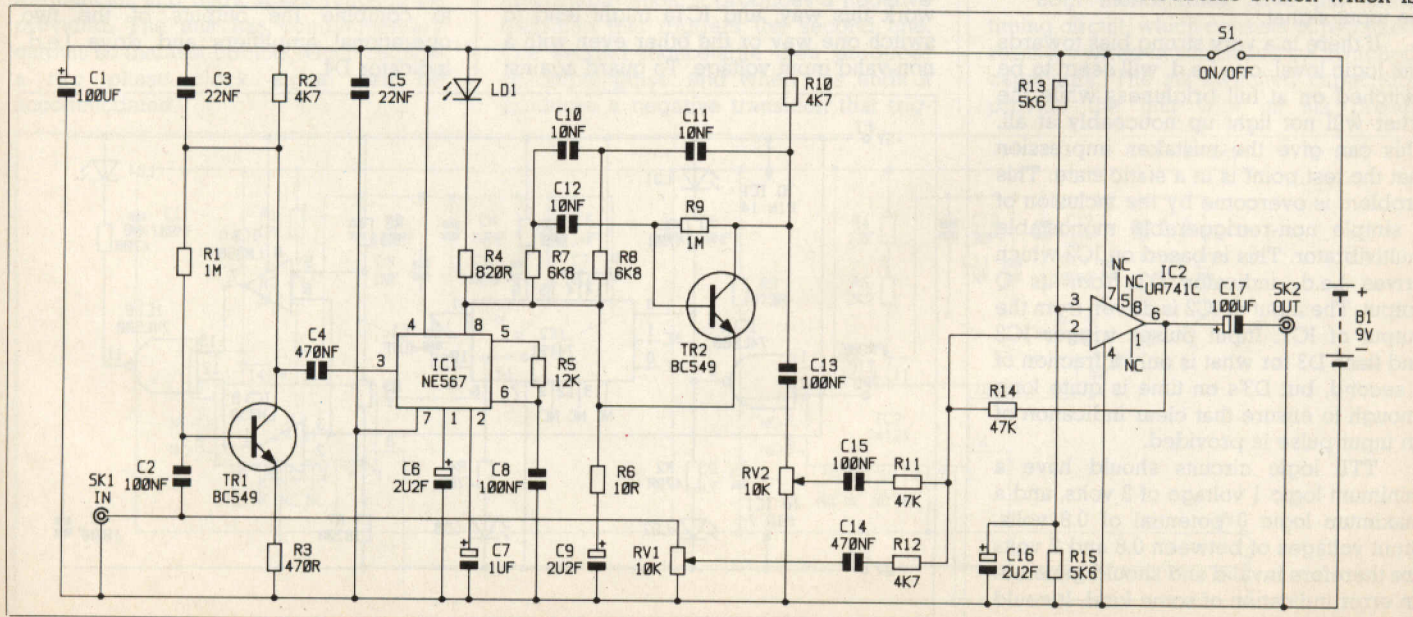
Morse Regenerator Circuit.

turned on during positive half cycles. The input signal is passed through this switch, and when lock is achieved only positive half cycles will be passed. These are smoothed and used to drive an open collector n.p.n. output transistor. Of course, if lock is not acheived, the switch will pass a mixture of negative and positive pulses, and the smoothed output signal will be insignificant. Therefore, the output stage only switches on when lock is achieved, and the high degree of selectivity required for this application is achieved due to the narrow lock-on range of the NE567. The centre frequency is a little over 1kHz, and due to the narrow bandwidth of the unit, tuning needs to be

very accurate (as it does with any highly selective c.w. filter).

The output of IC1 is used to control l.e.d. indicator D1, and a simple phase shift type sinewave oscillator which is based on TR1 and has an operating frequency of about 1kHz. The input signal and the output of the oscillator are combined at a simple mixer stage built around IC2. The input and oscillator volumes are controlled using RV1 and RV2 respectively. When searching for stations the input signal must be set at a reasonably high volume, but once a signal has been accurately tuned-in RV1 can be backed off. It can be set right back so that the input signal is completely

muted if desired, but most users prefer to have the input signal still audible in the background.

The output of the unit will drive most types of headphone at good volume. With low and medium impedance types it is usually best to use series connection of the phones, but parallel connection may be better with high impedance types. The current consumption of the circuit is about 14 milliamps under quiescent conditions, and something approaching double this figure during the periods when it is locked onto an input signal. A fairly high capacity battery (such as a PP9 type) is therefore needed in order to power the unit economically.

TTL Logic Tester

This logic tester is simple enough to be built as a probe style tool, but it is fairly comprehensive in its analysis of the test point. It gives indication of static low, static high, pulsing, and illegal logic levels. The status of the test point is indicated by four l.e.d.s. The unit is only intended for use on 5 volt TTL logic circuits incidentally. It provides loading that is approximately equal to one LS TTL input.

IC1a acts as a buffer stage at the input of the unit, and it drives l.e.d.s. D1 and D2. These indicate logic 1 and logic 0 levels respectively. Many test points in logic circuits are not conveniently at static levels, but are switching to and fro between the two logic states, often at a high frequency. Low frequency switching of the test point will be indicated by D1 and D2 flashing visibly. However, the switching rates of logic circuits are such that the flashing of the l.e.d.s will be so fast as to be imperceivable by the human eye. Both D1 and D2 will then appear to be switched on, with one being brighter than the other if the input signal spends more time at one logic level than the other. This is a useful feature as it gives a rough guide to the mark-space ratio of the input signal.

If there is a very strong bias towards one logic level, one l.e.d. will seem to be switched on at full brightness while the other will not light up noticeably at all. This can give the mistaken impression that the test point is in a static state. This problem is overcome by the inclusion of a simple non-retriggerable monostable multivibrator. This is based on IC2 which drives l.e.d. indicator D3 from its Q output. The input of IC2 is driven from the output of IC1. Input pulses trigger IC2 and flash D3 for what is only a fraction of a second, but D3's on time is quite long enough to ensure that clear indication of an input pulse is provided.

TTL logic circuits should have a minimum logic 1 voltage of 2 volts, and a maximum logic 0 potential of 0.8 volts. Input voltages of between 0.8 and 2 volts are therefore invalid and should generate an error indication of some kind. It could happen that an invalid input voltage would result in D1 and D2 both switching

Logic Tester.

on at something less than full brightness, with D3 not switching on and showing that this was due to an illegal input voltage rather than a pulsing signal. In practice things can not be guaranteed to work this way, and IC1a might tend to switch one way or the other even with a non-valid input voltage. To guard against

this a window discriminator circuit has been included in the unit. This detects input voltages of much more than about 0.8 volts but somewhat less than 2 volts. This circuit is based on IC3 and has IC1b to combine the outputs of the two operational amplifiers and drive l.e.d. indicator D4.
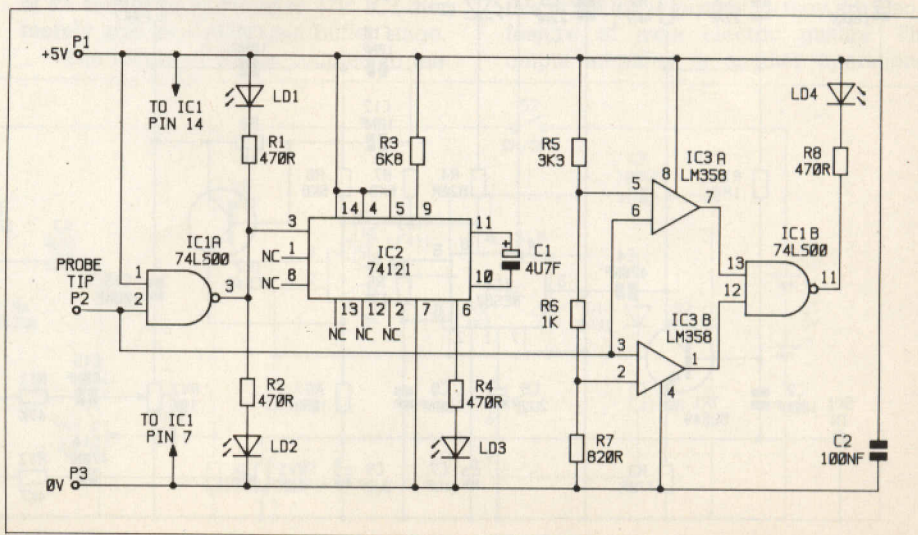
Logic Tester Circuit.

Power for the unit could be derived from its own power supply or batteries, but with this type of equipment it is generally much more satisfactory to tap off power from the circuit under test. The current consumption of the circuit is around 25 milliamps. Table 1 summarises the l.e.d. states for various types of input condition, and should prove to be helpful when first using the unit.

INPUT STATE	Static Low	Static High	Low Freq. Pulse	High Freq. Pulse	Invalid Voltage
D1	OFF	ON	FLASHING	ON-OFF	ON-OFF
D2	ON	OFF	FLASHING	ON-OFF	ON-OFF
D3	OFF	OFF	FLASHING	ON or FLASHING	OFF
D4	OFF	OFF	OFF	OFF★	ON

★ Note that with a high frequency pulsing signal D4 may switch on dimly. This is due to inadequacies in the switching speed of IC3 and does not indicate a fault at the test point.

Table 1. Summary of input conditions.

TTL Logic Pulser

The increasing dominance of logic circuits has led to the introduction of new types of test equipment where conventional instruments proved to be inadequate. A logic pulser is a good example of a piece of equipment which falls into this category, and it could reasonably be regarded as the logic equivalent of an audio signal generator. An audio signal generator is usually of limited value when testing digital circuits. Sinewaves are of no use for driving logic inputs, and squarewaves have their limitations (even if the signal generator can be set for an output level that can drive logic inputs properly). Ideally what is needed is a logic pulse generator that permits an output signal to be generated that has any desired high/low periods, with each one being individually adjustable.

Unfortunately, a good crystal controlled pulse generator covering a wide range of pulse times is a fairly complex and expensive piece of equipment. However, for many purposes something much more basic will suffice. This pulser unit has six switched durations, with separate duration controls for the high and low periods. The available times are approximately 1μs, 10μs, 100μs, 1ms, 10ms, and 100ms. Thus, if a waveform consisting of a 1μs pulse every 10ms was required, it would simply be a matter of setting the high control at 1μs and the low control at 10ms. This simple method of operation enables a useful range of frequencies and mark/space ratios to be provided. The unit has complementary outputs so that test circuits which require a two phase clock signal can be accommodated.
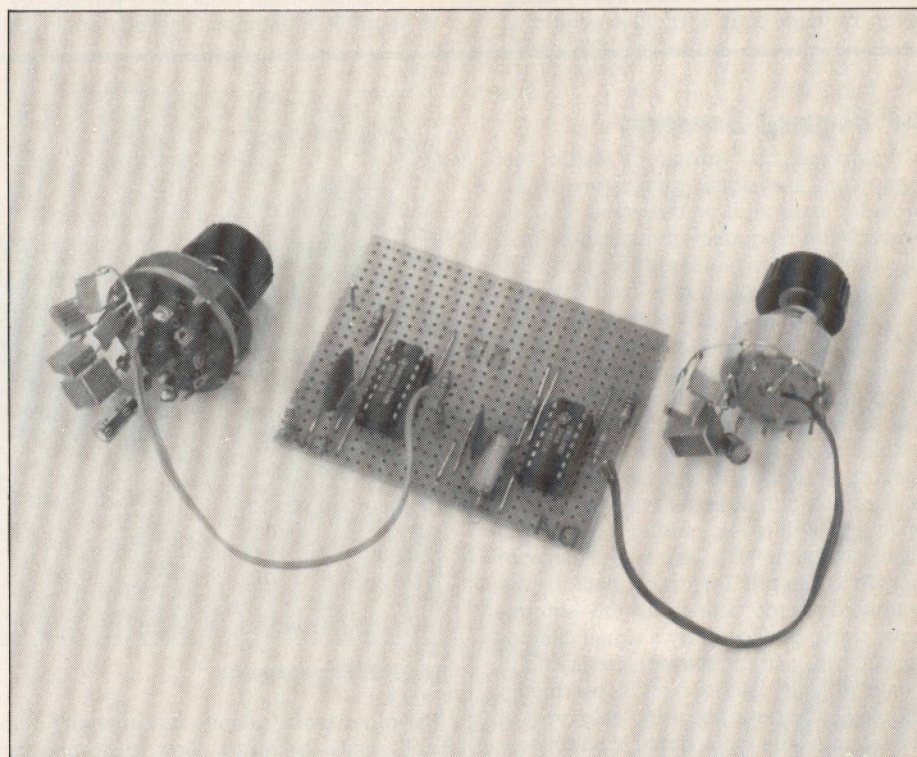
Logic Pulser.

The circuit is a form of 'ring' oscillator, and it is based on two 74121 monostable multivibrators. They are used in the negative edge triggered mode and have their inputs and Q outputs cross coupled. As the output pulse from the first monostable ends, it produces a negative transition that triggers the second one. The second monostable then produces an output pulse, and when this ends it produces a negative transition that trig-

gers the first monostable. This process continues indefinitely with the monostables continually retriggering each other, and a form of oscillation being produced. The high output period is controlled by IC2, while IC1 sets the low output period.

Both monostables have the same timing circuit, which consists of two fixed resistors wired in series and six switched capacitors. The six switched capacitors provide the unit with its six preset
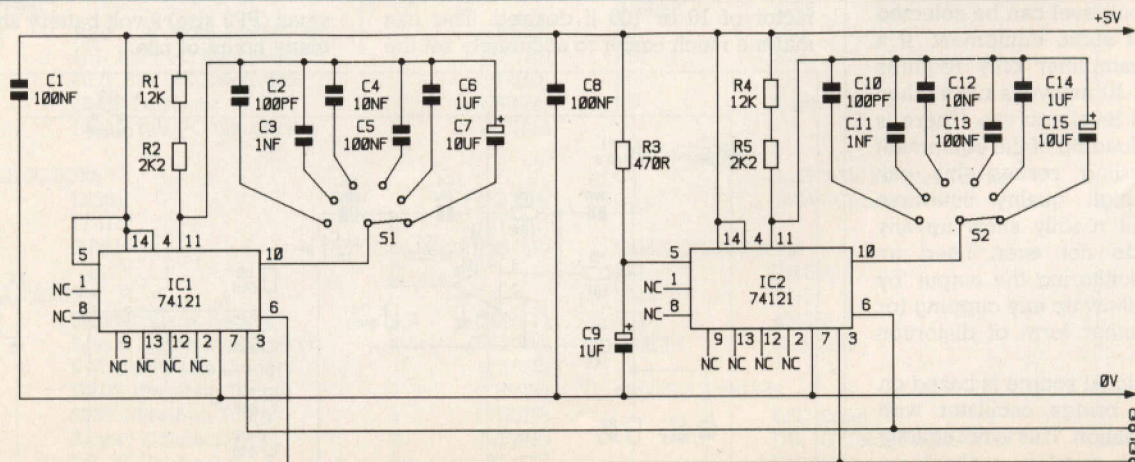
Logic Pulser Circuit.

high/low output periods, but obviously this system does not give the same degree of accuracy that is obtained from a crystal controlled circuit. However, pulse times should be accurate to within a few percent, which is good enough for most purposes. The exception is the 100ms setting, where the high tolerance of the electrolytic timing capacitor compromises accuracy. Tantalum capacitors should be used for C7 and C15 if optimum accuracy is required. If desired, by using seven or eight way switches additional

pulse times of 100ns and (or) 1s could be obtained. These would require timing capacitors of 10pF and 100μF respectively.

Although very plausible in theory, 'ring' oscillators often fail to operate. This is due to the lack of any initial impetus to get the circuit up and running. In this case R3 and C9 provide a trigger pulse at switch-on to an otherwise unused trigger input of IC2. This ensures reliable starting of the circuit.

Current drain from the 5 volt supply is about 40 milliamps. The unit could be

powered from a small 5 volt mains power supply, or from a fairly high capacity 9 volt battery by way of a 5 volt regulator. Another possibility is to use four AA size nickel-cadmium rechargeable cells, which will give a supply voltage which is close enough to the required 5 volt level. These cells can be fitted in a plastic holder and connected to the circuit via a standard PP3 style connector. In many cases it will probably be possible to simply tap off the 5 volt supply from the circuit under test.

AF Signal Source

Two popular forms of audio test equipment are signal generators which provide sine and squarewave outputs over a wide frequency range, and signal injectors which have some form of pulse or squarewave output at a fixed frequency. A good quality A.F. signal generator is certainly a real asset for the electronics workshop, but an instrument of this type is too costly and complex for those who will only undertake occasional audio testing. On the other hand, a signal injector is a bit too basic for much audio testing. The output is generally fixed and at quite a high level, making it difficult to check for something like a slight lack of gain in a circuit. Distortion can not be readily detected either, as the square-wave signal produced by a signal injector contains very strong harmonics. Trying to locate a faulty stage that is producing clipping is impossible using this type of test signal as the input signal is effectively clipped already!

For those who consider a signal generator to be beyond their needs but a signal tracer to be inadequate for their purposes, the obvious compromise choice is an A.F. signal source. This is effectively an audio signal generator, but having fixed frequency operation and no squarewave output. A unit of this type can be used for most types of audio testing, the obvious exception being that it is of no use for frequency response testing. It can be used as an audio signal injector though, and the ability to set the output at any desired level ensures that an appropriate output level can be selected for any piece of audio equipment. If a microphone preamplifier only requires an input level of 10 millivolts r.m.s., then that is the signal level you use. There is no need for overloading of the equipment and the misleading results this can produce. The high quality sinewave output signal will readily show up any clipping. You do not even need an oscilloscope - monitoring the output 'by ear' will readily show up any clipping (or practically any other form of distortion come to that).

This audio signal source is based on the usual Wien bridge oscillator with thermistor stabilisation. This is not exactly the latest thing in modern technology, and it is a type of circuit that has been used extensively for many years now. On

The A.F. Signal Source.

the other hand, despite its simplicity it is not easily bettered. Low distortion is assured by the use of a bifet operational amplifier as the basis of the unit. Also, unlike most other forms of gain stabilisation, the thermistor type provides what for most practical purposes can be regarded as zero distortion. It is also very effective at stabilising the output level against changes in output loading. In this case the output level is approximately 2.8 volts peak to peak (1 volt r.m.s.). However, RV1 is a variable attenuator which can be used to set the output at any level from zero to this maximum figure. There is also a three step attenuator, and S1 can be used to reduce the output by a factor of 10 or 100 if desired. This can make it much easier to accurately set the

desired output level when a low amplitude output is required.

The operating frequency of the circuit is approximately 1kHz. With only a single operating frequency it obviously makes sense to choose one at roughly the middle of the audio range, and 1kHz would seem to be the obvious choice. However, if desired the output frequency can be changed by altering the value of C3 and C4. The output frequency is inversely proportional to the value of these components (e.g. doubling their value halves the circuit's operating frequency).

The current consumption of the circuit is only about 3.5 milliamps, and a small (PP3 size) 9 volt battery should give many hours of use.
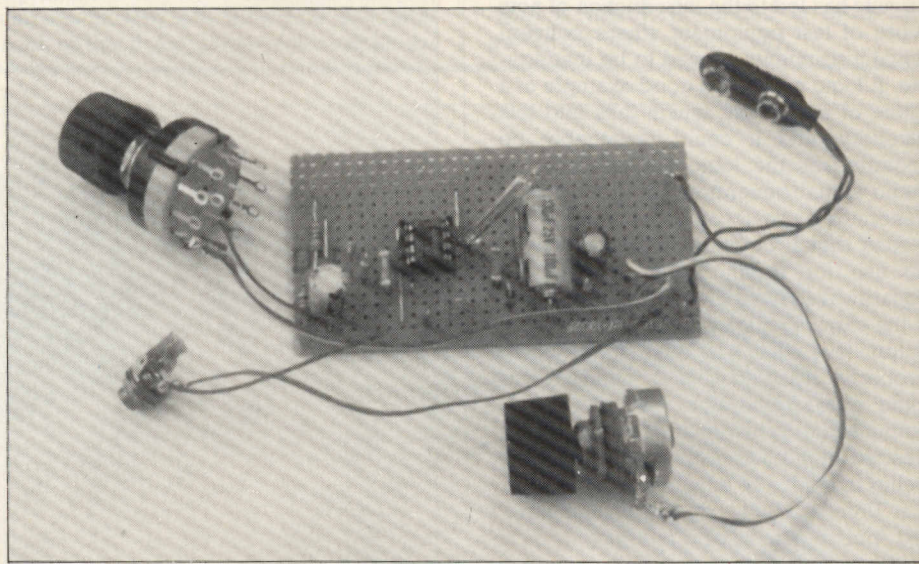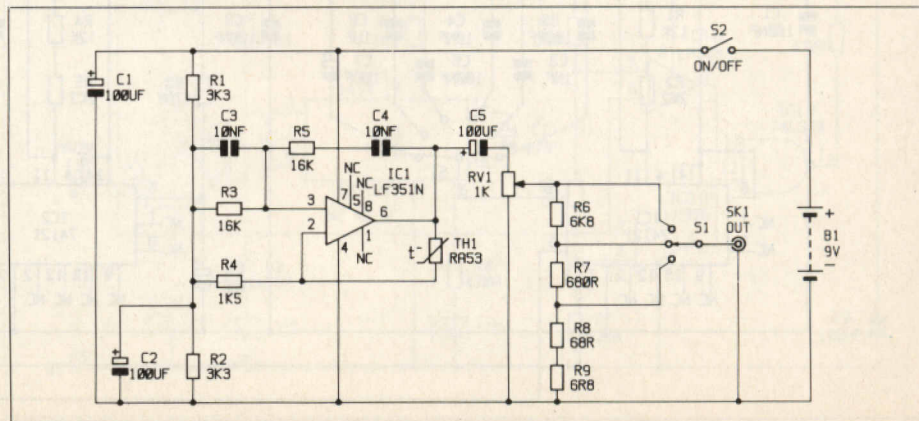
A.F. Signal Source Circuit.

MORSE REGENERATOR PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,9	1M	2	(M1M)
R2,10,12	4k7	3	(M4K7)
R3	470R	1	(M470R)
R4	820R	1	(M820R)
R5	12k	1	(M12K)
R6	10R	1	(M10R)
R7,8	6k8	2	(M6K8)
R11,14	47k	2	(M47K)
R13,15	5k6	2	(M5K6)
RV1,2	10k Log Pot	2	(FW22Y)

CAPACITORS

C1	100μF 10V Axial Electrolytic	1	(FB48C)
C2,8,13,15	100nF Polyester	4	(BX76H)
C3	22nF Polyester	1	(BX72P)
C4,14	470nF Polyester	2	(BX80B)
C5	22nF Ceramic	1	(BX01B)
C6,9,16	2μ2F 100V PC Electrolytic	3	(FF02C)
C7	1μF 100V PC Electrolytic	1	(FF01B)
C10,11,12	10nF Polyester	3	(BX70M)
C17	100μF 10V PC Electrolytic	1	(FF10L)

SEMICONDUCTORS

IC1	NE567	1	(QH69A)
IC2	μA741C (8 pin)	1	(QL22Y)
TR1,2	BC549	2	(QQ15R)
D1	5mm Red LED	1	(WL27E)

MISCELLANEOUS

SK1	3.5mm Jack Socket	1	(HF82D)
SK2	Standard ¼ inch Jack Socket	1	(HF91Y)
S1	SPST Ultra-Min Toggle	1	(FH97F)
B1	9 Volt (PP9 size) Battery	1	(FM05F)
	DIL IC Holder 8-pin	2	(BL17T)
	Battery Connector	1	(HF27E)
	LED Holder	1	(FM38R)

GUITAR HEADPHONE AMPLIFIER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	47k	1	(M47K)
R2,3	22k	2	(M22K)
R4	470k	1	(M470K)
R5,6	100k	2	(M100K)
R7	560R	1	(M560R)
R8	180R	1	(M180R)
R9	4k7	1	(M4K7)
RV1	22k Log Pot	1	(FW23A)

CAPACITORS

C1	10μF 10V Axial Electrolytic	1	(FB48C)
C2,3	1μF 100V PC Electrolytic	2	(FF01B)
C4	4μ7F 63V PC Electrolytic	1	(FF03D)
C5	330nF Polyester	1	(WW47B)
C6,7	100μF 10V PC Electrolytic	2	(FF10L)

SEMICONDUCTORS

IC1	LF351	1	(WQ30H)
IC2	LF411	1	(QY27E)
D1,2	OA91	2	(QH72P)

MISCELLANEOUS

SK1	Standard Jack Socket	1	(HF91Y)
SK2	3.5mm Stereo Jack Socket	1	(FK20W)
B1	9 Volt (PP3 size) Battery	1	(FK62S)
S1	DPDT Ultra-Min Toggle	1	(FH99H)
S2	SPST Ultra-Min Toggle	1	(FH97F)
	Battery Connector	1	(HF28F)
	DIL IC Holder 8-pin	2	(BL17T)

AF SIGNAL SOURCE PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2	3k3	2	(M3K3)
R3,5	16k	2	(M16K)
R4	1k5	1	(M1K5)
R6	6k8	1	(M6K8)
R7	680R	1	(M680R)
R8	68R	1	(M68R)
R9	6R8	1	(M6R8)
RV1	1k Lin Pot	1	(FW00A)

CAPACITORS

C1	100μF 10V Axial Electrolytic	1	(FB48C)
C2,5	100μF 10V PC Electrolytic	2	(FF10L)
C3,4	10nF Polyester	2	(WW29G)

SEMICONDUCTOR

IC1	LF351N	1	(WQ30H)

MISCELLANEOUS

TH1	R53 or RA53 Thermistor	1	(FX62S)
S1	3-way 4-pole Rotary Switch	1	(FF76H)
S2	SPST Ultra-Min Toggle	1	(FH97F)
SK1	3.5mm Jack Socket	1	(HF82D)
B1	9 Volt (PP3 size) Battery	1	(FK58N)
	Battery Connector	1	(HF28F)

TTL LOGIC PULSER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,4	12k	2	(M12K)
R2,5	2k2	2	(M2K2)
R3	470R	1	(M470R)

CAPACITORS

C1,8	100nF Ceramic	2	(YR75S)
C2,10	100pF Ceramic	2	(WX56L)
C3,11	1nF Polyester	2	(WW22Y)
C4,12	10nF Polyester	2	(WW29G)
C5,13	100nF Polyester	2	(WW41U)
C6,14	1μF Polyester	2	(WW53H)
C7,15	10μF 50V PC Electrolytic	2	(FF04E)
C9	1μF 100V PC Electrolytic	1	(FF01B)

SEMICONDUCTORS

IC1,2	74121	2	(QX73Q)

MISCELLANEOUS

S1,2	6-way 2-pole Rotary Switch	2	(FF74R)
	DIL IC Holder 14-pin	2	(BL18U)

TTL LOGIC TESTER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,2,4,8	470R	4	(M470R)
R3	6k8	1	(M6K8)
R5	3k3	1	(M3K3)
R6	1k	1	(M1K)
R7	820R	1	(M820R)

CAPACITORS

C1	4μ7F 63V PC Electrolytic	1	(FF03D)
C2	100nF Ceramic	1	(YR75S)

SEMICONDUCTORS

IC1	74LS00	1	(YF00A)
IC2	74121	1	(QX73Q)
IC3	LM358	1	(UJ34M)
D1,2,3,4	Red LED	4	(WL27E)

MISCELLANEOUS

	LED Bezel	4	(FM38R)
	DIL IC Holder 8-pin	1	(BL17T)
	DIL IC Holder 14-pin	2	(BL18U)

'Hello Who's Calling?'

Bell's first telephone

by J.K. Hearfield Part 5

Postwar: The 700-Type Telephone

In 1908 there were just half a million telephones in the UK. Twelve years later there were a million, and twelve years after that, two million. The number of telephones has been rising at 7% or so each year since anyone first bothered to count them, and it's still growing at the same steady rate (Figure 1).

By 1946 the Telephone 332 was more than ten years old, and the Post Office decided that technology had advanced far enough to make it worthwhile to start work on a new design. Even if the performance of the new telephone proved to be no better than its predecessor, new manufacturing methods (such as printed circuits) should guarantee that it would cost less to make, and this was becoming increasingly important. More than 2 million telephones had been added to the UK network since the 332 first saw service. A new telephone design could be expected to last for at least fifteen years – until, say, 1965 – and by then there could easily be 10 million telephones in the country. So it was clear from the outset that one of the main design aims must be to keep production costs as low as possible.
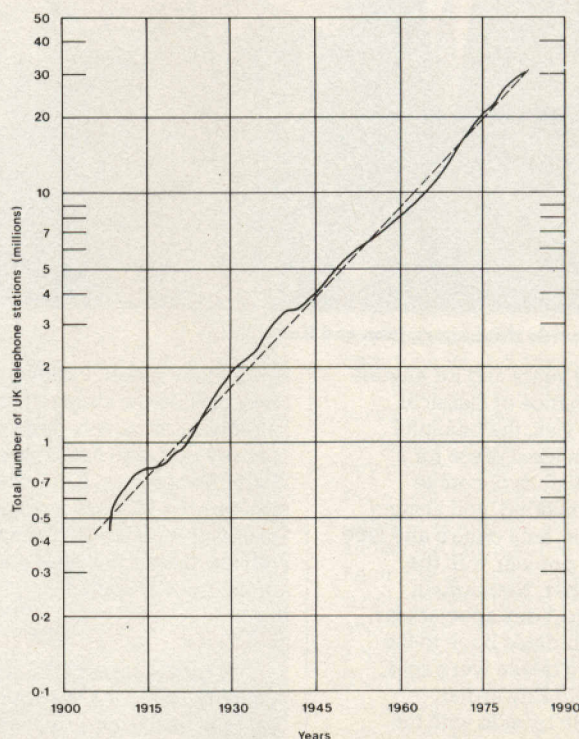
Figure 1. The number of telephones in Britain doubles every 12 years.

Transmission Testing

The first prototypes of the new telephone did not appear for some years. It proved unexpectedly difficult to develop a better microphone, and then just as difficult to be certain that the new telephone really was better than its predecessor. The problem came down to this: how can the transmission performance of a telephone be judged objectively? What does 'better' mean?
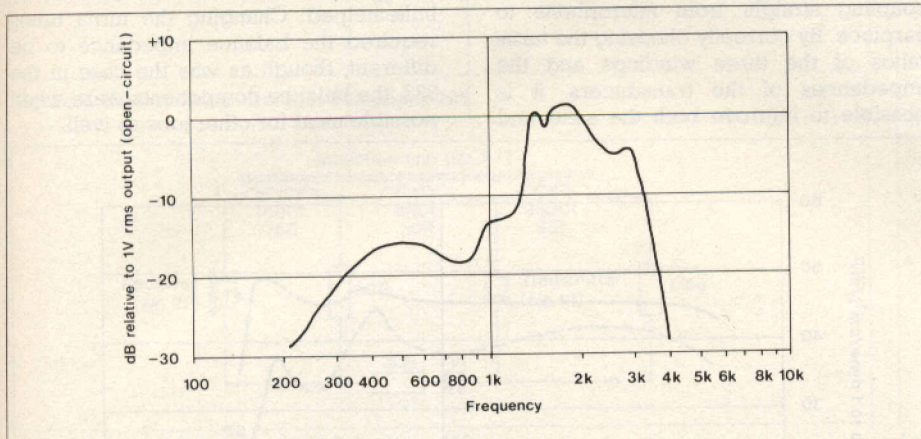

Figure 2. The Transmitter Inset No.13 was used, despite its highly non-linear frequency response.

Telephones obviously exist so that human beings can communicate with other human beings. This being so, a good test should be to arrange for two strangers to hold a conversation using first one type of telephone and then another, and get them to compare the two. Personal bias could be removed by using a sufficiently large group of subjects. The trouble is, human beings are all so different. Some people talk much more loudly than others, some are slightly deaf (though they may not know it), and some prefer to talk as much as they can without really listening. To get meaningful results it would be necessary to use many hundreds of people from all over the country. Besides, the sending and receiving characteristics of telephones depend on the line conditions. The type and length of line between the telephone and the exchange can make a big difference; even the type of exchange matters. Collecting and processing sufficient data simply to decide between one finished design and another would be a huge undertaking. It boggles the mind to think of using this exercise as a routine testing tool.

Yet design engineers need a way of assessing how close they have come to a finished product. There must be an objective definition of what they are trying to achieve, and an agreed set of tests - a yardstick - that can be applied to their design to see if the target has been reached.

To bridge the gap between subjective and objective, the first step was to compare peoples' reactions to a change in, say, line length with some other parameter that can be measured in the laboratory. It was quickly found that the dB loss at certain frequencies correlated

nicely with the subjective results. This meant that engineers could predict how people would feel about changes in this one parameter without needing to measure their reactions each time. The same technique allowed different exchanges and even different induction coils to be compared, and greatly reduced the amount of speech testing required.

Next, the idea of a 'conversation' was boiled down to its essence. The talker was made to read a fixed list of a thousand or so nonsense syllables, whilst the listener wrote down what he (or more often, she) thought was said. The need for a large group of people was removed by using specially-trained talkers who could maintain a constant voice level and speak at a fixed distance from the microphone. The 'articulation tests' were done in acoustically-dead rooms, of course, and various levels of room noise were simulated using loudspeakers. This method of subjective assessment remained standard for many years. I myself

took part in one such test in the late 1960's, and a weirdly uncomfortable experience it was too, rather like being the only one at a seance. "Is anybody there?" I kept wondering.

Articulation testing was used to establish the maximum length of each type of local line which could be used to link a telephone to its exchange and still give acceptable speech performance. To make life simpler for the line planners, the limit was expressed not in dB but as a Transmission Equivalent Resistance (TER), measured in ohms. As such it sat easily beside the signalling limit, also expressed in ohms, which specified the maximum line length at which dial pulses could still be recognised unambiguously. (Dial-pulse distortion became unacceptably high at a line length much shorter than that at which the bell would no longer ring or the microphone feed current became too low, because of the pulse-rounding effects of line capacitance.)

Sensitivity

A telephone will only work properly when the cable linking it to the local exchange is short enough to be within both the signalling limit and the TER limit. Telephones close to an exchange are straightforward: the short distance allows the use of thin, high resistance wire. Those customers who live on the fringes of an exchange area however pose more of a problem. The line planners must ensure that the cable serving them is just adequate to meet the maximum safe resistance and TER limits for their telephones. This can be very expensive, because not only is it necessary to provide a much longer cable run, the cable itself must have lower resistance

Photo 1. Telephone 706.

per unit length; in other words, it must use thicker wire. If the TER limit could be increased, cheaper cable could be used, and perhaps also fewer new exchanges would have to be built.

So the second major design aim for the new telephone was to make it much more sensitive. The Telephone 332's 660 ohm TER limit was to be increased by 50% to the nice round figure of 1,000 ohms.

There was only one possible way of increasing sensitivity - the transducers had to be improved. The standard microphone at that time was the Transmitter Inset No.13, and work began trying to design a better one. Unfortunately, although the carbon-granule microphone was obviously far from perfect (Figure 2), it was the result of many years of continual refinement and the technology had advanced almost as far as it was ever going to get. It might have been possible to achieve a smoother frequency response, but not significantly greater sensitivity.

It was a different story with the earpiece – the receiver, as it was called. STC engineers abandoned the traditional approach and came up with a new idea (Figure 3). The key concept in the 'rocking-armature' receiver is that the diaphragm – the bit that moves the air, like a loudspeaker cone – need not and indeed should not itself be part of the magnetic circuit. Separating and optimising these components resulted in a receiver having good sensitivity in a reliable, low-cost package. The frequency response of the new design (the 4T) is compared with that of its predecessor (the 2P) in Figure 4.

Transmission Circuit

Given at least one better transducer, the next step was to redesign the induction coil in order to trade-off the greatly increased receiver sensitivity for smaller but more balanced improvements in the performance of the complete telephone (Figure 5). The induction coil is there to couple energy from the microphone to line, and from line to the earpiece, without at the same time allowing much direct coupling straight from microphone to earpiece. By correctly choosing the turns ratios of the three windings and the impedances of the transducers, it is possible to improve both the send and receive sensitivities of the telephone.

The transmission circuit of the new telephone is shown in Figure 6. The instrument was known as the Type 700 (perhaps because even then the Post Office knew it would still be around in the 1970's) and it looks superficially very like the 332's transmission circuit (Figure 7). The induction coils are however quite different, see Table 1.

The lower winding resistances reduced the internal losses - not much, but every little helped. Changing the turns ratios required the balance impedance to be different, though as was the case in the 332, the balance components were when possible used for other jobs as well.
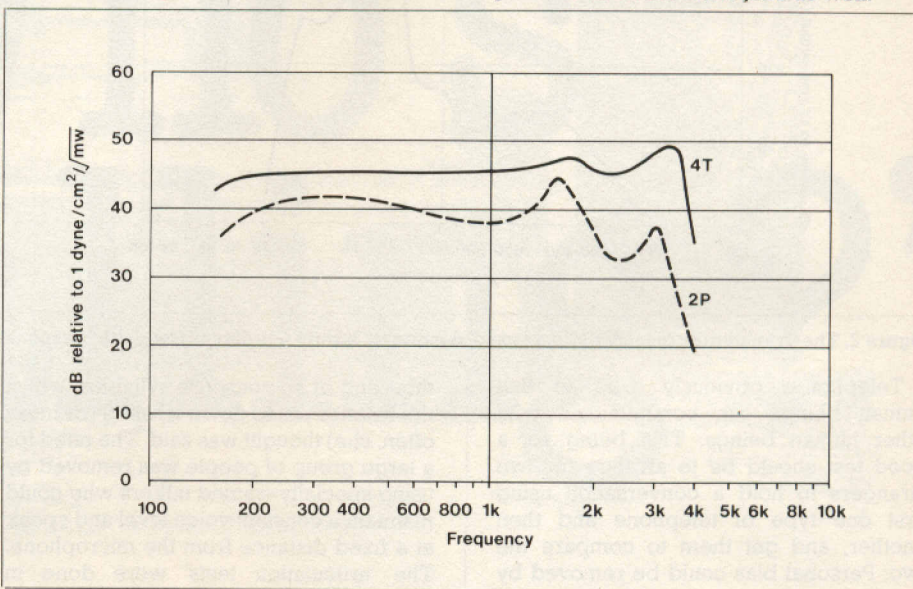

Figure 4. The new Receiver Insert (4T) was more sensitive than its predecessor (2P), and had a flatter frequency response.
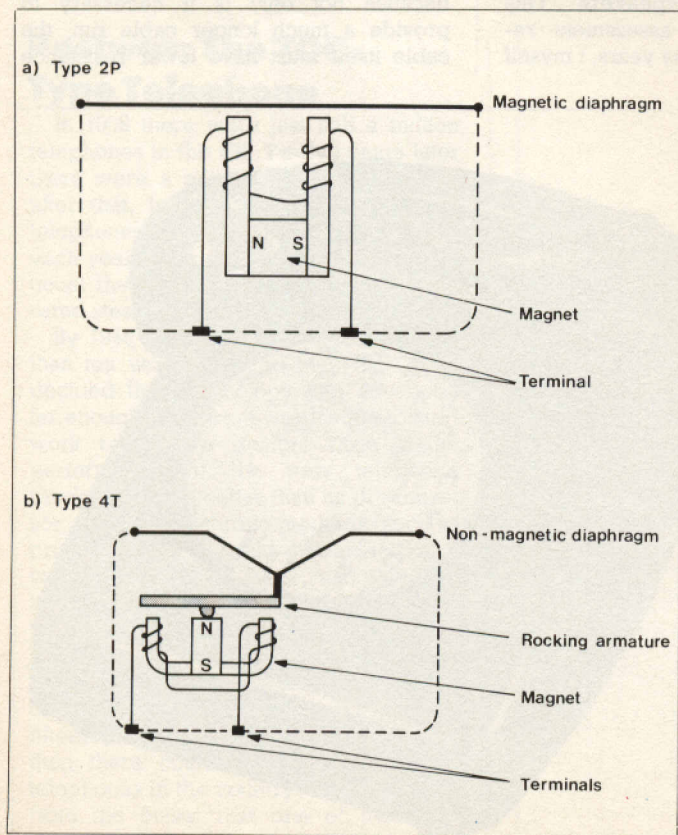

Figure 3. Construction of the 'rocking armature' receiver Type 4T compared to the earlier Type 2P.
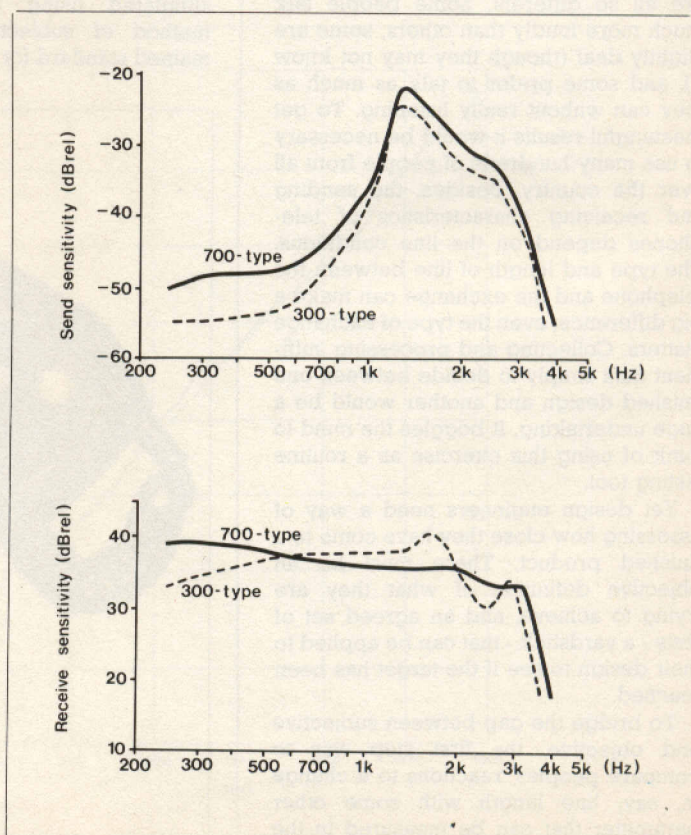

Figure 5. Send and receive sensitivities for 300 type and 700 type telephones.
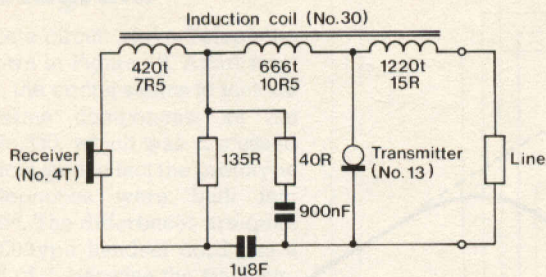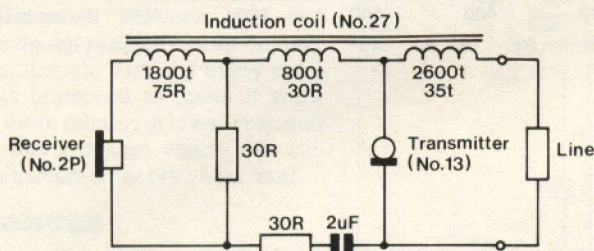
Figure 6. Transmission circuit of Telephone 700.

Figure 7. Transmission circuit of Telephone 332.

Figure 8. Dialling circuit of Telephone 700.

Dialling Circuit

Dialling poses certain special problems of its own. The Dial-Off-Normal contacts must provide a low resistance path for the current pulses whilst at the same time ensuring that the earpiece is short-circuited (to prevent loud clicks from being heard). A resistance-capacitance suppression network must be connected across the dial contacts, because the line current flows through large inductors (at the exchange end) and breaking the current in an inductive circuit would otherwise cause sparks at the dial contacts. The values of resistance and capacitance cannot be chosen arbitrarily. They affect the make-to-break ratio of the pulses received by the exchange, and so the 'spark quench' circuit used in the Telephone 700 had to be similar to that of the 332, the telephone it was intended to replace, which used 30 ohms in series with $2\mu F$ (Figure 8). The induction coil itself was pressed into service as the 30 ohm resistor, along with the $1.8\mu F$ bell DC blocking capacitor. The original plan had been to keep this capacitor at $2\mu F$, but it ended up 10% smaller so that both it and the $0.9\mu F$ capacitor demanded by the balance network would both fit into the same can.

Transmission Performance

Prototypes of the new 700 telephone were given an in-house field trial as PBX extensions in selected regional Post Office buildings. (A PBX is a Private Branch Exchange – that is, a small exchange serving usually just one building and owned by the company that owns or occupies the building.) Users were almost unanimous in finding them too loud, particularly on internal calls. This
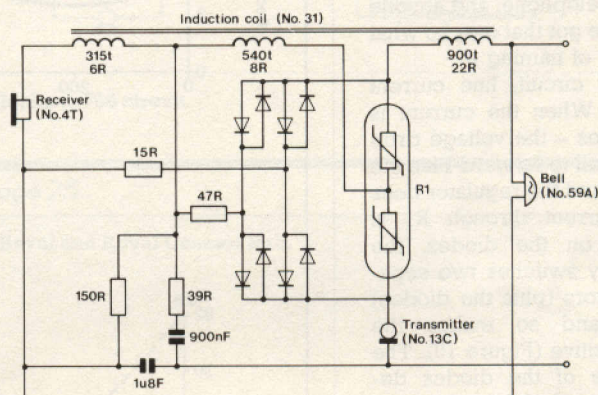

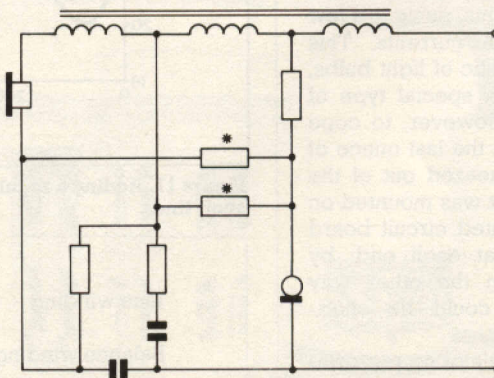Figure 9. Transmission circuit of Telephone 706, showing the regulator.

Figure 10. Simplified transmission circuit of the Telephone 706. The regulator reduces sensitivity by shunting the transmission circuit when the line current is high.
Components marked ★ have low resistance at high line currents and negligibly high resistance when line current is small.

was an unexpected problem: the new telephone had been deliberately made more sensitive in order to improve performance on long lines, but on short lines – and PBX lines are invariably very short – it was now too sensitive. Some inexpensive way had to be found to reduce the sensitivity on short lines only, and ideally to make the sensitivity independent of line length.

The answer lay in the realisation that a short line has high line current as well as low loss: both are aspects of the same thing. Current-dependent resistors existed, so in principle line current could be used to control the telephone's performance automatically. Interestingly, when the French PTT were faced with this problem they chose a quite different solution – each telephone installed was individually adjusted by the installer to make its line current fall within certain fixed limits.

The final transmission circuit, modified to include a regulator, is shown in Figure 9. This design variant became the standard production 700-type telephone, and is known as the Telephone No.706. In the mid 1950's, when the Type 706 was launched, it was still considered unnecessary to give a product a name. There was only one standard telephone, and anyone wanting a telephone got that one, so what would be the point of naming it?

In the regulator circuit, line current flows through R1. When the current is small – on long lines – the voltage drop across R1 is too small to forward-bias the (selenium) diodes, and the regulator does nothing. If the current through R1 is sufficient to turn on the diodes, the regulator effectively switches two separate shunting resistors (plus the diodes) into the circuit and so makes the telephone less sensitive (Figure 10). The effective resistance of the diodes depends on their degree of forward bias, which in turn depends on line current. The circuit is symmetrical to allow for inadvertent line reversals.

The sensing resistor R1 in series with the microphone adds extra loss to the circuit, even when the regulator is ineffective on long lines. To minimise the loss, the value of R1 is arranged to be just a few ohms at low currents, rising to a few tens of ohms at high currents. This behaviour is characteristic of light bulbs, and in fact R1 is just a special type of under-run light bulb. However, to cope with situations in which the last ounce of sensitivity must be squeezed out of the telephone, the regulator was mounted on a separate plug-in printed circuit board with connector pads at each end; by plugging the board in the other way round, the regulator could be short-circuited.

The effect of the regulator on performance was dramatic. Most people find a 1dB change in level only just perceptible, so the graphs of Figure 11 are really demonstrating that the send, receive and sidetone levels have all became almost independent of the line length for lines
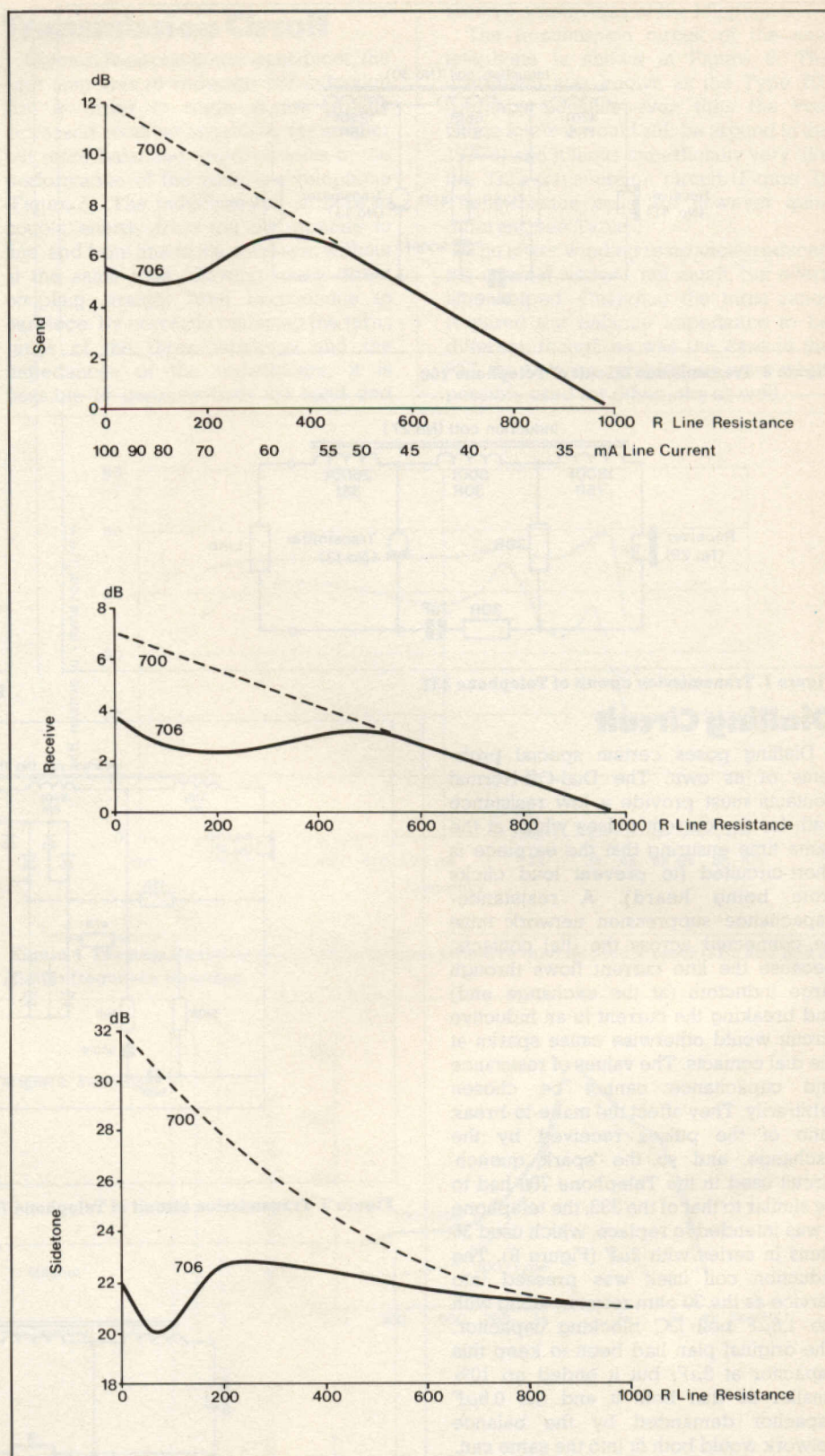
Figure 11. Adding a regulator to the basic 700 circuit improved all aspects of performance on short lines.

	Coil No. 27 (332)	Coil No.30 (700)
Line winding	2600 turns	1220 turns
	35 ohms	15 ohms
Balance winding	800 turns	666 turns
	30 ohms	10.5 ohms
Receiver winding	1800 turns	420 turns
	75 ohms	7.5 ohms
Turns ratios	1.4:0.4:1	2.9:1.6:1

Table 1. Comparing the induction coils of the 332 and the 700.

Circuit Diagram

The complete circuit of the Telephone No.706 is shown in Figure 12. Apart from the regulator, the circuit seems to include much the same components as the Telephone No.330, which was discussed in the last article, and in fact the prototype 700-type telephones were built into 300-type cases. The differences are quite minor: the 700-type handset cord has 4 wires instead of 3, because the transmission circuit was cheaper that way, and the 700-type lacks the 300-type's $0.1\mu F$ microphone bypass capacitor (which had turned out not to be essential after all). The major differences between the two telephones do not really show up on their schematics, though. Virtually every component was improved to make it work better and more reliably at lower cost, and the result was a design which was still being manufactured twenty years later.

References

Interested readers may like to consult the following articles published in The Post Office Electrical Engineers' Journal. 'The rocking-armature receiver' – JSP Roberton, April 1956. 'The new 700-type telephone' – HJC Spencer & FA Wilson, July 1956. 'The new 700-type table telephone – Telephone No.706' – HJC Spencer & FA Wilson, April 1959.
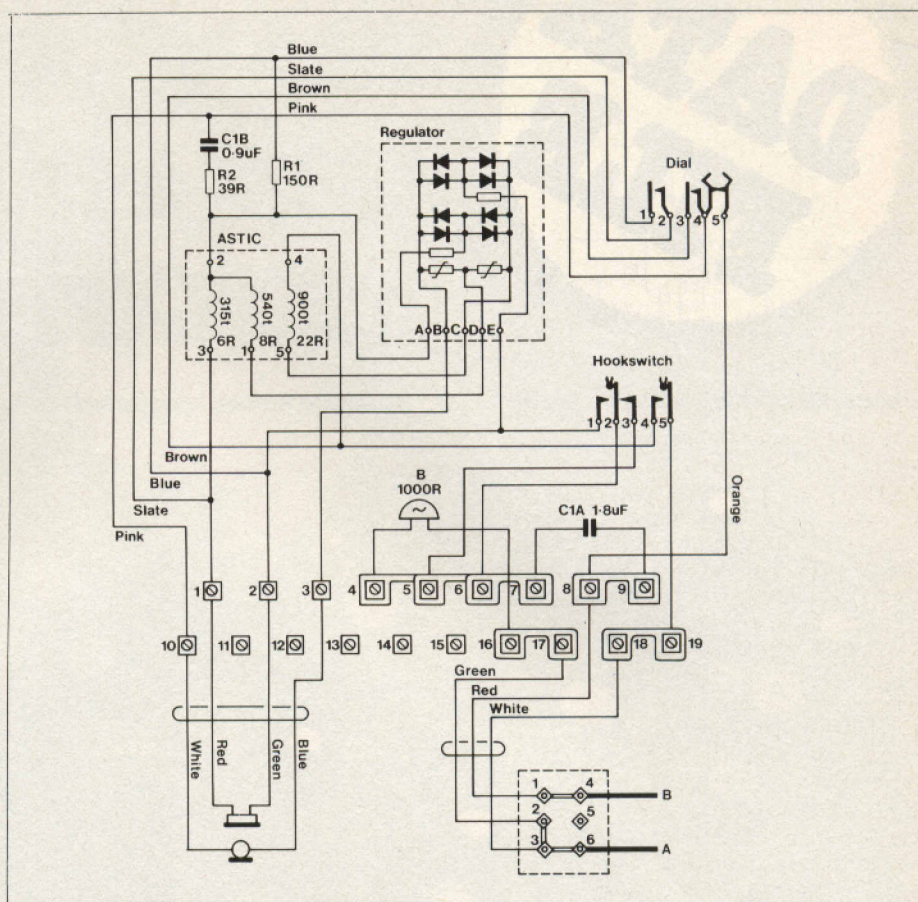

Figure 12. Telephone 706 circuit.

Maplin come to Nottingham, continued from page 25.

hobbyists. Andy is currently studying City & Guilds electronics and is apparently the joker of the pack, although the rest of the staff do not appreciate his sense of humour. Kevin is also a semi-professional musician, playing bass electric guitar.

So if you live in the Nottingham area, pop in to the Maplin shop and you will be assured of a warm welcome. Even if you don't live in the vicinity of Nottingham, make a day of it, bring the family, see the sights and visit the best electronics store around!

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Photos provided courtesy of Nottingham City Council.

LM13700 DUAL TRANSCONDUCTANCE OPERATIONAL AMPLIFIER
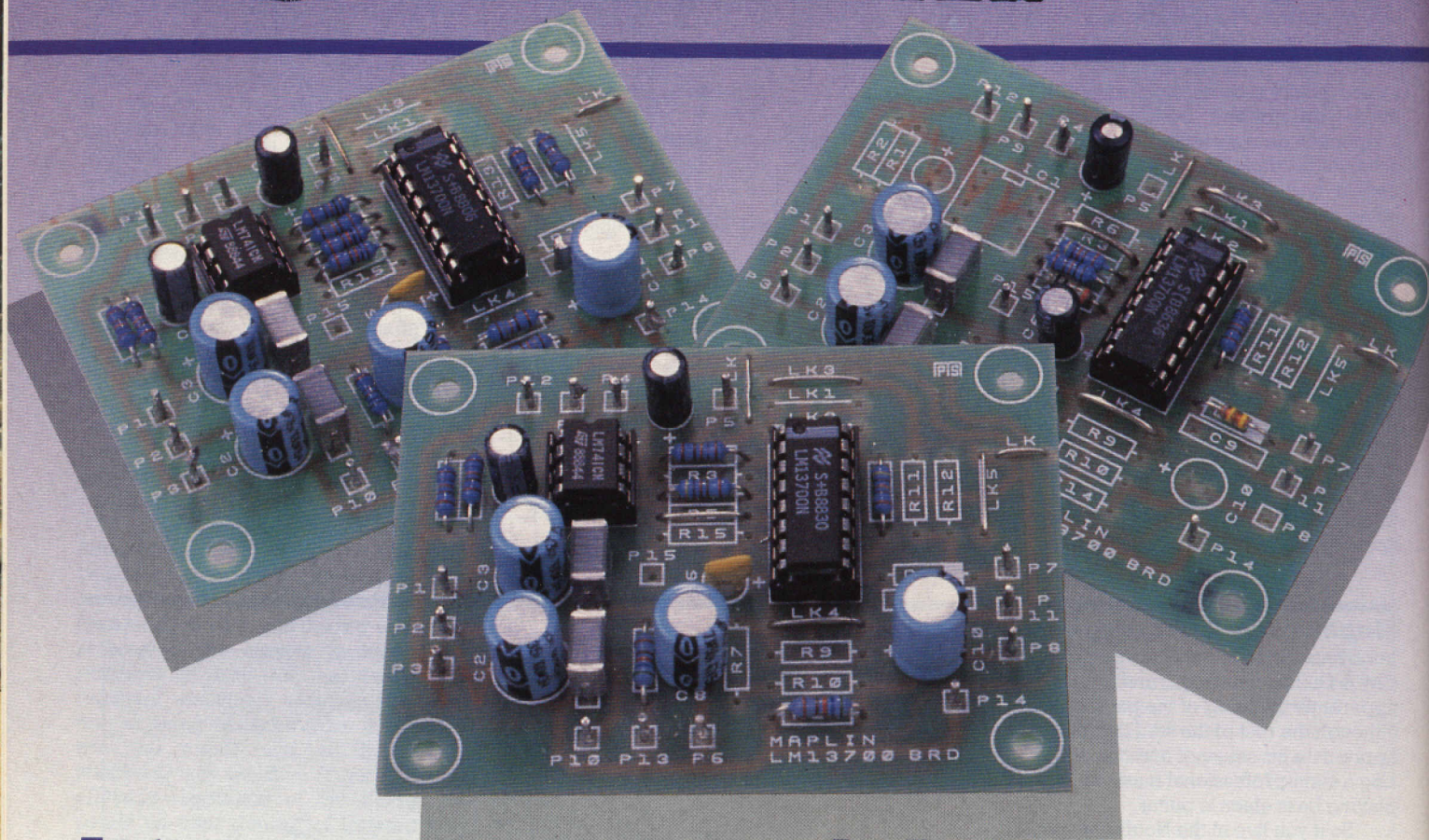
Features
★ Amplifiers Very Closely Matched
★ Wide Supply Voltage Range (±2V to ±15V)
★ High Impedance Buffers
★ PCB available

Applications
★ Voltage Controlled Filters
★ Voltage Controlled Amplifiers
★ Voltage Controlled Oscillators
★ Sample and Hold

Introduction

The LM13700 is a dual transconductance operational amplifier featuring low distortion and a wide dynamic range. The package contains two transconductance op-amps which share a common power supply input but are otherwise completely separate. Two high impedance buffers, designed to suit the dynamic range of the op-amp are included in the package. Figure 1 shows the IC pinout and Table 1 shows the electrical characteristics of the device.

Voltage Controlled Filter

A transconductance op-amp such as the LM13700 can form the basis of a versatile voltage controlled filter (VCF). The LM13700 is particularly suitable for use in a VCF circuit as the required buffers are included in the IC. Figure 2 shows the circuit of a basic voltage controlled low pass filter; this circuit acts as a unity gain buffer below the cut-off frequency. Above the cut-off frequency the circuit provides

Parameters	Operating Conditions	Minimum	Typical	Maximum
Power Supply Voltage		±2V		±15V
Differential Input Voltage				±5V
Input Offset Voltage Iabc	5µA	0.4mV	4mV	
Forward Transconductance (gm)		6700µS	9600µS	13000µS
gm tracking			0.3dB	
Peak Output Voltage:				
Unloaded, Iabc	5µA–500µA			
Positive		+12V	+14.2V	
Negative		−12V	−14.4V	
Common Mode Range		±12V	±13.5V	
Input Resistance		10kΩ	26kΩ	
Slew Rate	Unity Gain Compensated		50V/µs	

Note: Above specifications based on Supply Voltage ±15V, Amplifier Bias Current (Iabc) 500µA, Operating temperature 25°C and pins 2 & 5 open circuit (unless specified).

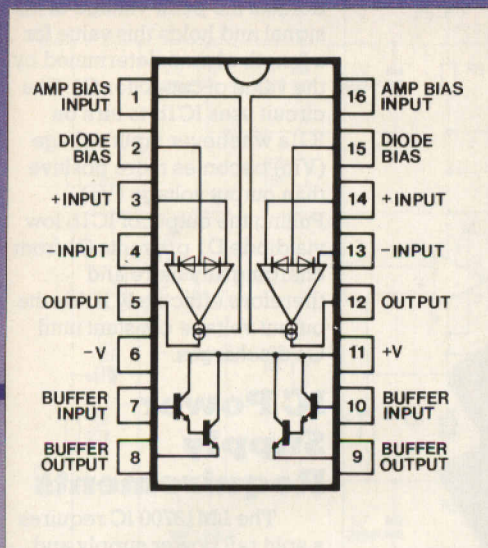**Table 1. Electrical characteristics of LM13700 transconductance op-amp.**
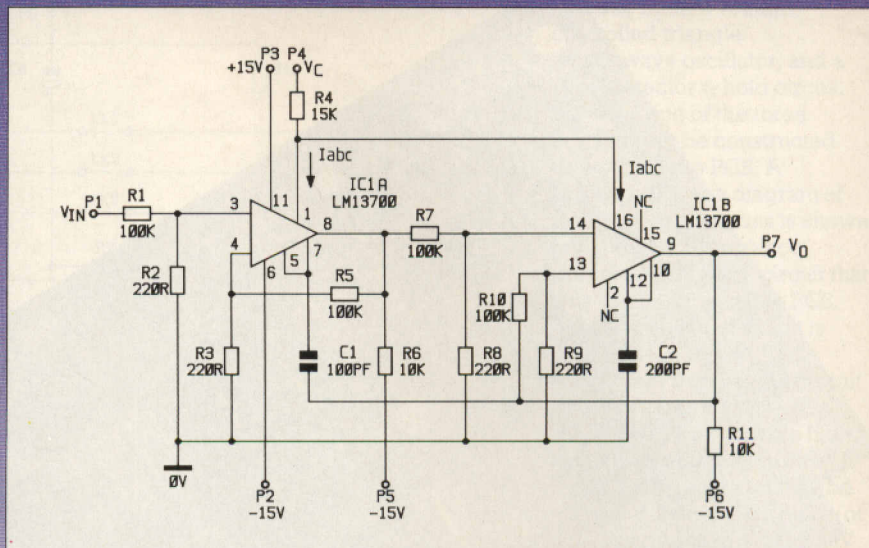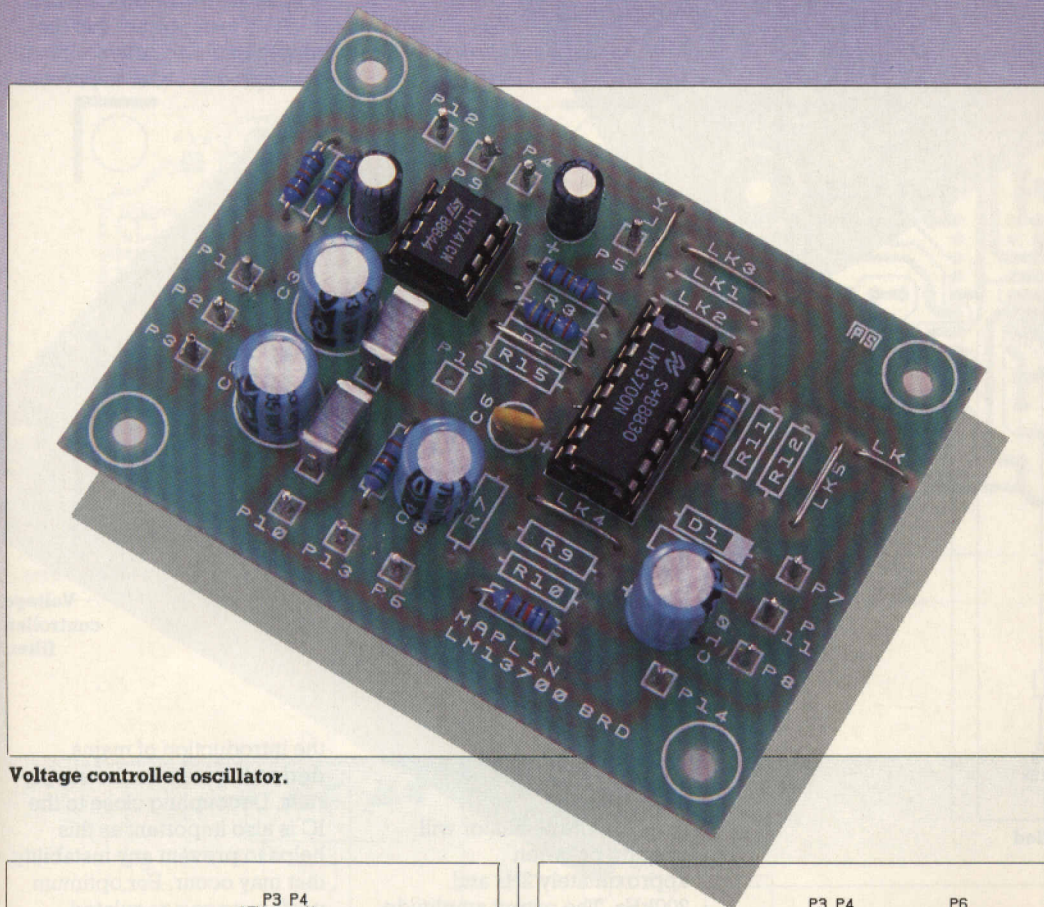
Figure 1. IC pinout diagram.

Figure 3. Example of a two pole butterworth filter.

Voltage controlled oscillator.

a roll off of 6dB per octave. Higher order filters may be produced using additional amplifiers as illustrated by the two pole butterworth filter shown in Figure 3. The circuit diagram of a typical state variable filter is shown in Figure 4; this provides both a low pass and a bandpass characteristic with a roll off of approximately 6dB per octave.

Voltage Controlled Oscillator

Effective voltage controlled oscillators can be realized using the LM13700. Figure 5 shows an example of a voltage controlled oscillator circuit that will produce both square and triangle wave outputs. The frequency of the oscillator is determined by the amplifier bias current (Iabc) which may be varied between around 10nA to 1mA; with the component values shown in
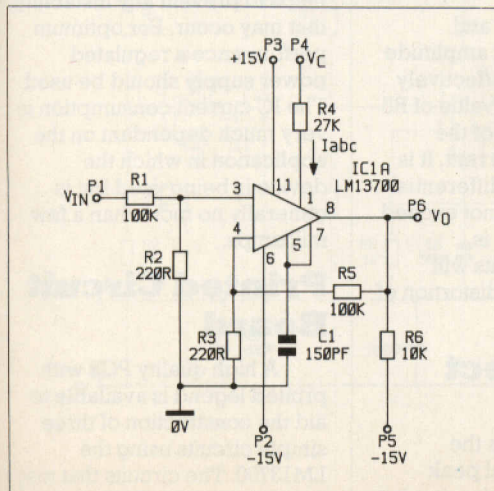
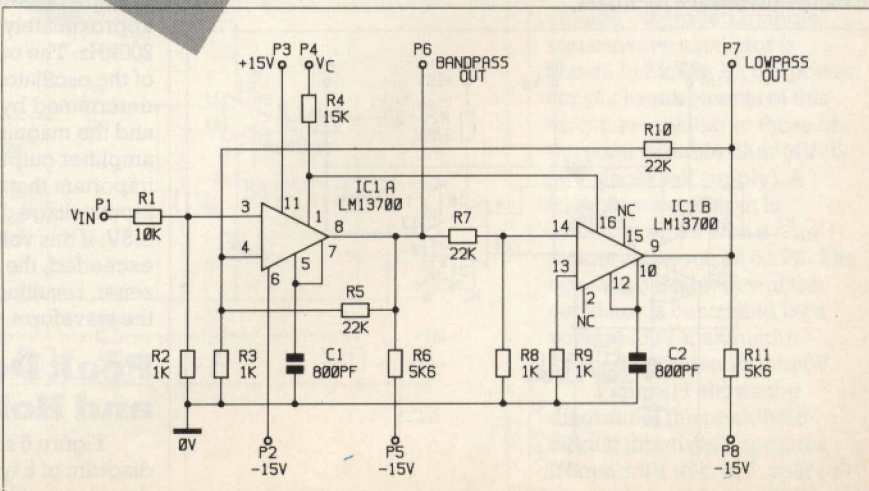

Figure 2. A typical voltage controlled low pass filter.

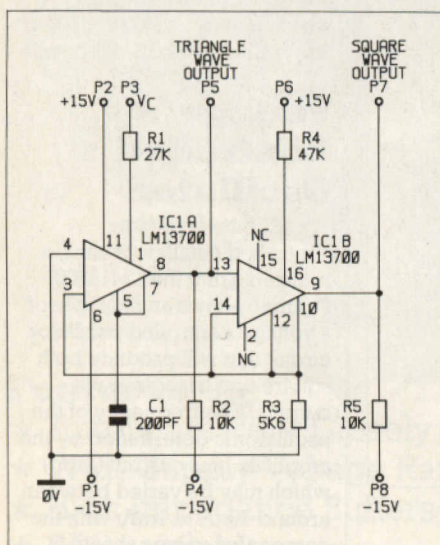**Figure 4. A typical voltage controlled state variable filter.**
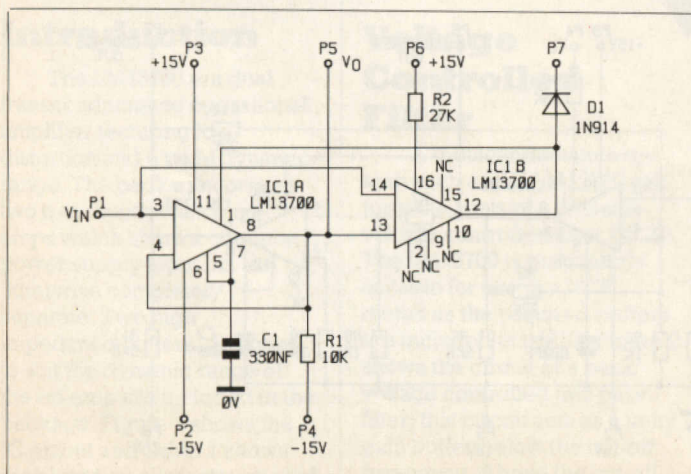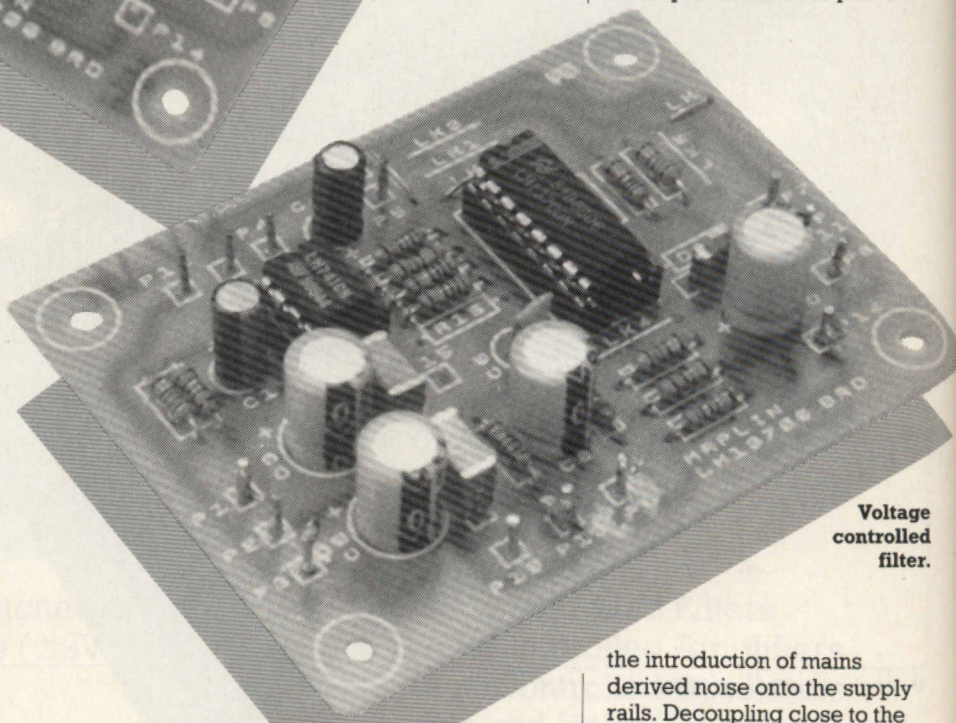
Peak and
hold.

detects the peak voltage of the signal and holds this value for a length of time determined by the value of capacitor C1. The circuit uses IC1b to turn on IC1a whenever input voltage (Vin) becomes more positive than output voltage (Vo). Pulling the output of IC1b low via diode D1 prevents C1 from charging any more and therefore effectively holds the output voltage constant until C1 discharges.

IC Power Supply Requirements

The LM13700 IC requires a split rail power supply and will operate over a wide range of voltages between ±2V and ±15V. It is important that the supply is adequately decoupled in order to prevent

Voltage
controlled
filter.

Figure 5. Example of a voltage controlled triangle/squarewave oscillator.

Figure 6. A typical peak detector and hold circuit.

Figure 5, the oscillator will operate between approximately 2Hz and 200kHz. The output amplitude of the oscillator is effectively determined by the value of R5 and the magnitude of the amplifier output current. It is important that the differential input voltage does not exceed ±5V; if this voltage is exceeded, the inputs will zener, resulting in distortion of the waveform.

Peak Detect and Hold

Figure 6 shows the diagram of a typical peak detector and hold circuit using the LM13700; this circuit

the introduction of mains derived noise onto the supply rails. Decoupling close to the IC is also important as this helps to prevent any instability that may occur. For optimum performance a regulated power supply should be used. The IC current consumption is very much dependant on the application in which the device is being used but is generally no more than a few milliamps.

Printed Circuit Board

A high quality PCB with printed legend is available to aid the construction of three simple circuits using the LM13700. The circuits that may be built using the PCB are a voltage controlled state
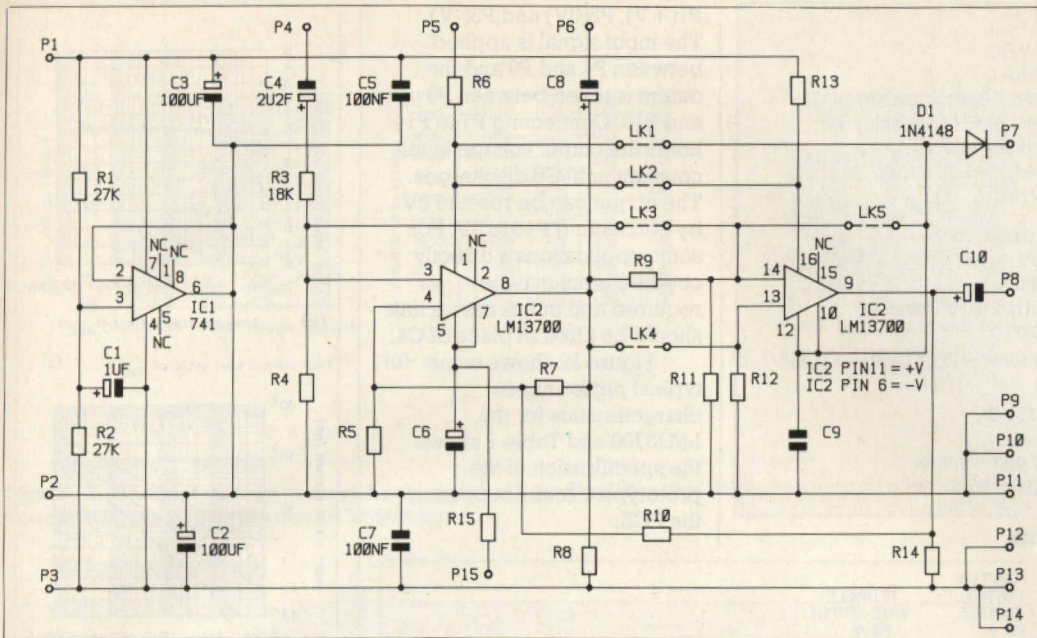
Figure 7. Combined circuit to which the PCB is designed.
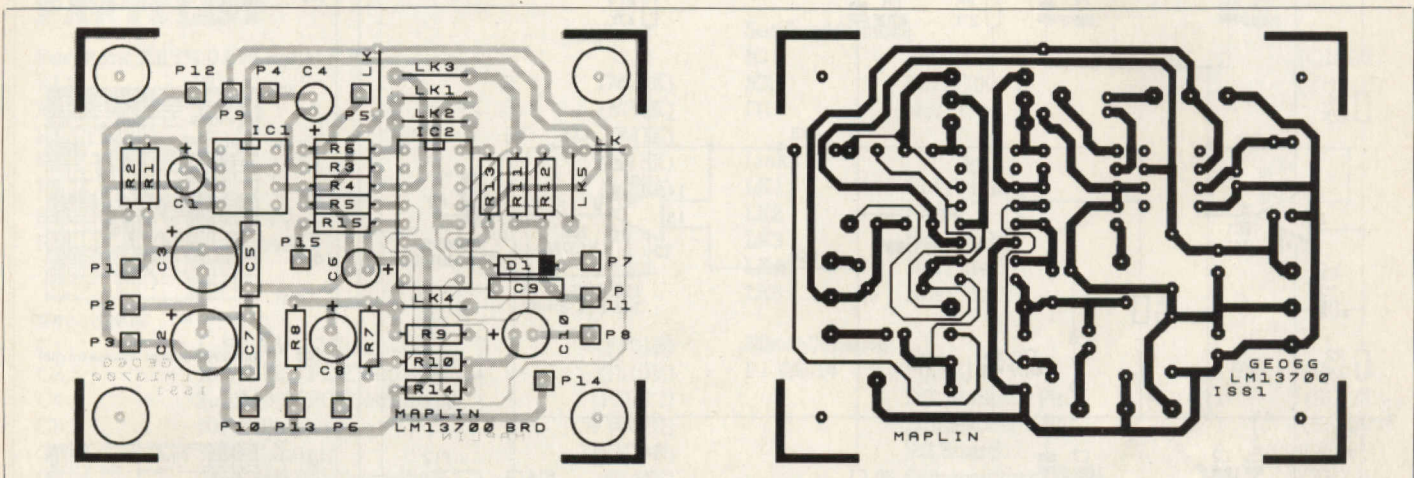
Figure 8. PCB track layout.
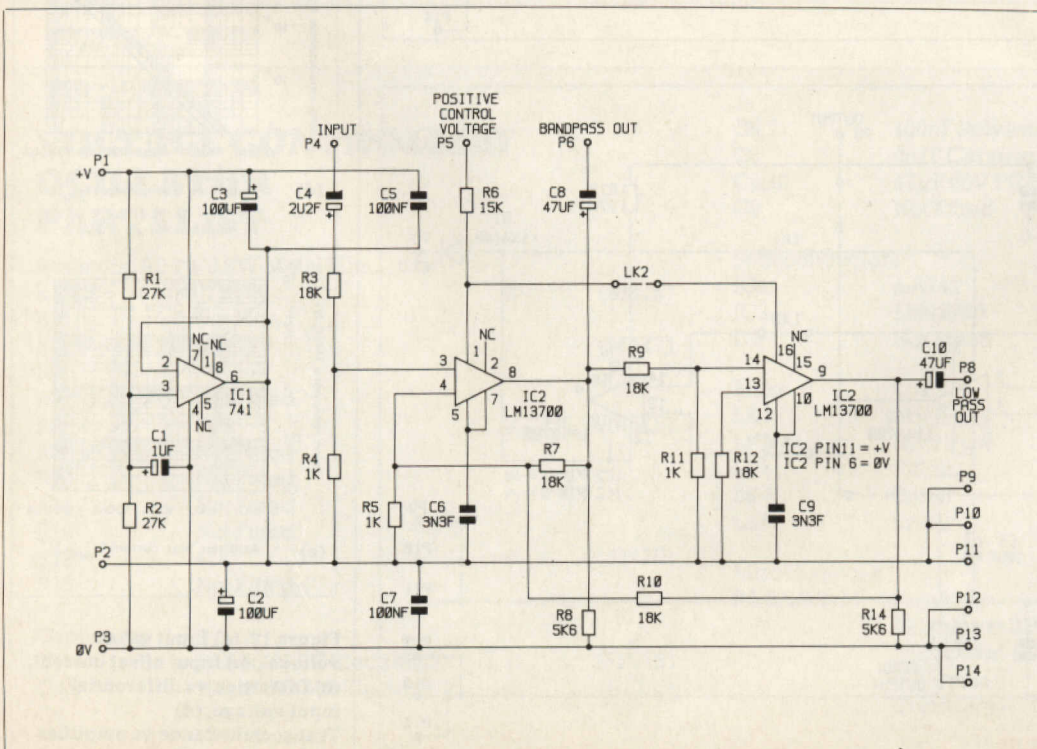
Figure 9. Circuit to build the VCF.

variable filter, a voltage controlled triangle/squarewave oscillator, and a peak detector & hold circuit.

Any one of the three circuits may be constructed using the same PCB. A combined circuit diagram of the three applications is shown in Figure 7 for reference purposes; this is the circuit that was used to design the PCB, the track layout of which is shown in Figure 8.

Figure 9 shows the circuit diagram of the voltage controlled state variable filter; this circuit operates from a single rail supply and may be powered from a wide range of voltages between 4V and 30V (maximum). Power supply connections are made to P1(+V) and P3(0V). An input signal is applied between P4 & P12 and the filter produces a bandpass output on P6, with a low pass output on P8. A control voltage (30V maximum) applied between P5 and 0V determines the operating frequency of the filter (see Table 2).

The circuit diagram of the voltage controlled triangle/squarewave oscillator is shown in Figure 10; the power supply requirements of this circuit are similar to those of the state variable filter (4V to 30V single rail supply). A triangle wave output is available on P6 with a squarewave output on P8. The operating frequency of the oscillator is controlled by a voltage (30V maximum) applied between P5 and 0V.

Figure 11 shows the diagram of the peak/hold circuit; this circuit operates from a ±4V to ±15V, split rail supply only. Power supply connections are made to

Voltage Controlled state variable filter:

Power supply voltage	30V DC
Current drain	10mA
Bandpass filter centre frequency	20Hz-20kHz (variable)
Low pass filter cut-off frequency	20Hz-20kHz (variable)
Roll off	6dB per octave
Load impedance	10kΩ
Maximum input voltage	1V rms

Voltage controlled triangle/squarewave oscillator:

Power supply voltage	30V
Current drain	10mA
Output frequency	20Hz-20kHz (variable)
Load impedance	10kΩ
Output voltage	5V peak to peak (with 30V supply)

Peak/hold circuit:

Power supply voltage	±15V DC
Current drain	8mA
Maximum input voltage	8V peak to peak
Load impedance	1kΩ

Table 2. Specification of prototype circuits.

P1(+V), P2(0V) and P3(-V). The input signal is applied between P4 and P9 and the output is taken between P6 and P10. Connecting P7 to P14 holds the output voltage level constant until C6 discharges. The output can be reset to 0V by connecting P15 to 0V. For some applications a directly coupled input may be required and in this case a link should be fitted in place of C4.

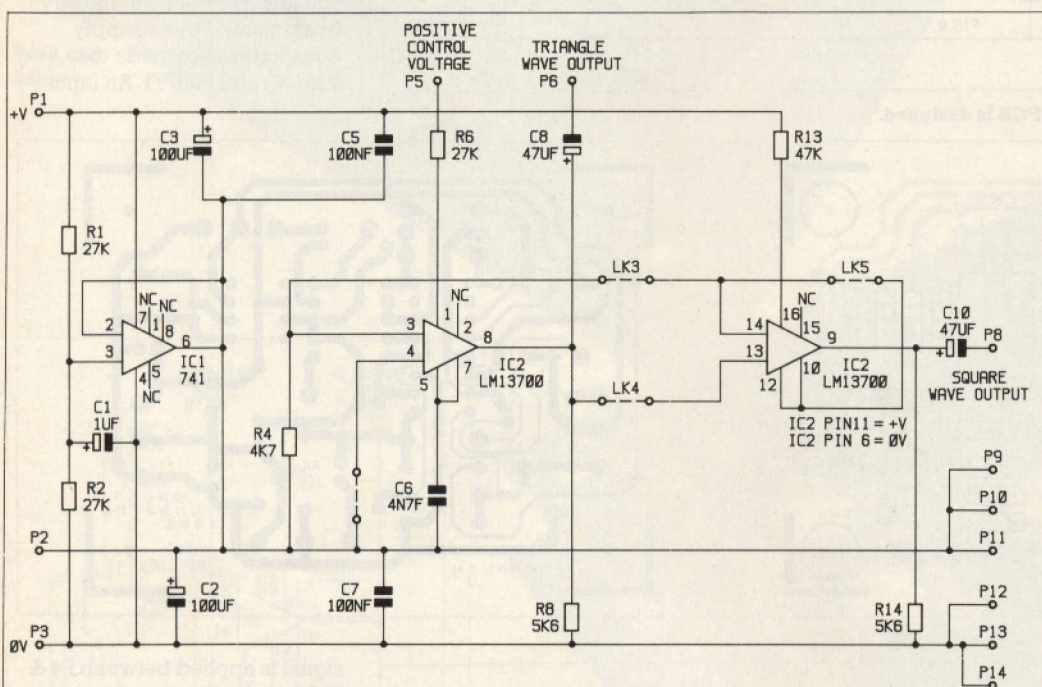Figure 12 shows some typical performance characteristics for the LM13700 and Table 2 shows the specification of the prototype circuits built using the PCB.
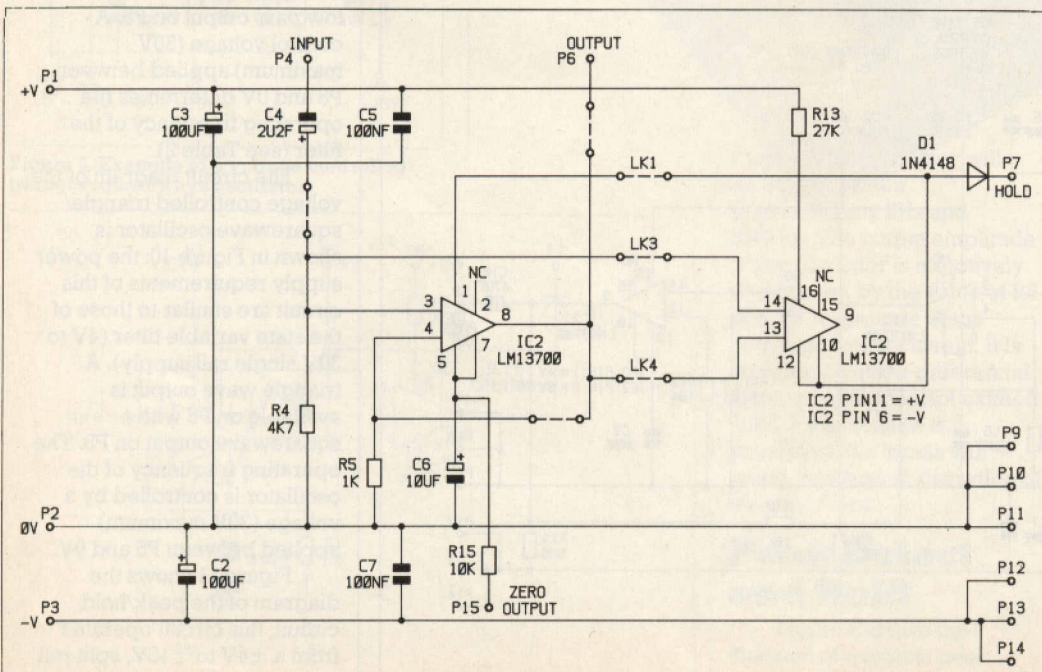
Figure 10. Circuit to build the oscillator.

Figure 11. Circuit to build the peak and hold.
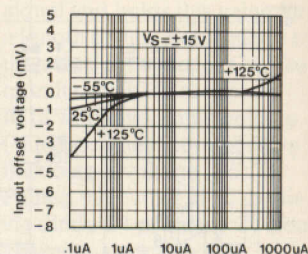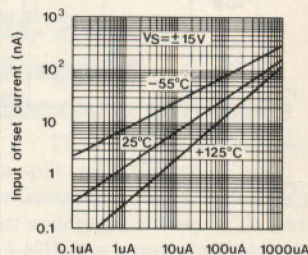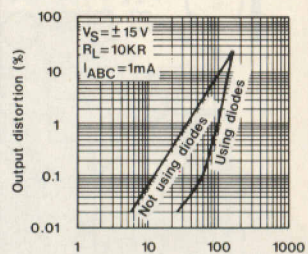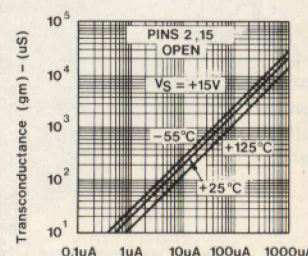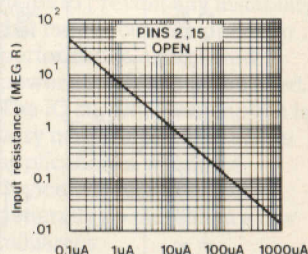
Figure 12. (a) Input offset voltage, (b) Input offset current, (c) Distortion vs differential input voltage, (d) Transconductance vs amplifier bias current, (e) Input resistance vs amplifier bias current.
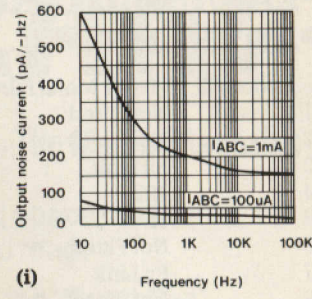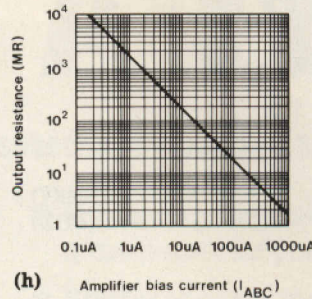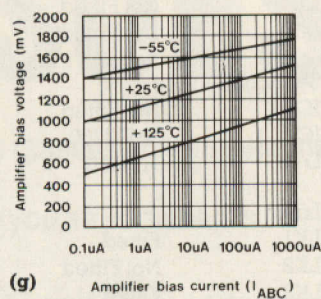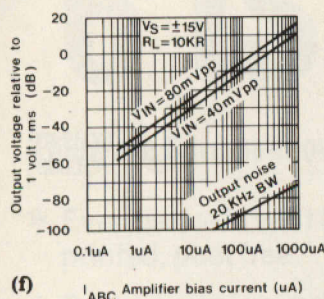
Figure 12. (f) Output voltage vs amplifier bias current, (g) Amplifier bias voltage vs amplifier bias current, (h) Output resistance vs amplifier bias current, (i) Output noise current vs frequency.

VOLTAGE CONTROLLED FILTER PARTS LIST

Resistors: All 1% 0.6W Metal Film

R1,2	27k	2	(M27K)
R3,7,9,10,12	18k	5	(M18K)
R4,5,11	1k	3	(M1K)
R6	15k	1	(M15K)
R8,14	5k6	2	(M5K6)
R13	Not Fitted		
R15	Not Fitted		

Capacitors

C1	1μF 100V PC Electrolytic	1	(FF01B)
C2,3	100μF 35V PC Electrolytic	2	(JL19V)
C4	2μ2F 100V PC Electrolytic	1	(FF02C)
C5,7	100nF Polylayer	2	(WW41U)
C6	3n3F Ceramic	1	(WX74R)
C8,10	47μF 50V PC Electrolytic	2	(JL16S)
C9	3n3F Polylayer	1	(WW25C)

Semiconductors

IC1	μA741	1	(QL22Y)
IC2	LM13700	1	(YH64U)
D1	Not Fitted		

Links

LK1	Not Fitted	
LK2	Fitted	
LK3	Not Fitted	
LK4	Not Fitted	
LK5	Not Fitted	

Miscellaneous

P1-6,8-14	Pins 2145	1 Pkt	(FL24B)
	DIL Socket 8 Pin	1	(BL17T)
	DIL Socket 16 Pin	1	(BL19V)
	PC Board	1	(GE06G)
	Constructors Guide	1	(XH79L)

VOLTAGE CONTROLLED OCILLATOR PARTS LIST

Resistors: All 1% 0.6W Metal Film

R1,2,6	27k	3	(M27K)
R3	Not Fitted		
R4	4k7	1	(M4K7)
R5	Fit Link		
R7	Not Fitted		
R8,14	5k6	2	(M5K6)
R9	Not Fitted		
R10	Not Fitted		
R11	Not Fitted		
R12	Not Fitted		
R13	47k	1	(M47K)
R15	Not Fitted		

Capacitors

C1	1μF 100V PC Electrolytic	1	(FF01B)
C2,3	100μF 35V PC Electrolytic	2	(JL19V)
C4	Not Fitted		
C5,7	100nF Polyester	2	(WW41U)
C6	4n7F Ceramic	1	(WX76H)
C8,10	47μF 50V PC Electrolytic	2	(JL16S)
C9	Not Fitted		

Semiconductors

IC1	μA741	1	(QL22Y)
IC2	LM13700	1	(YH64U)
D1	Not Fitted		

Links

LK1	Not Fitted	
LK2	Not Fitted	
LK3	Fitted	
LK4	Fitted	
LK5	Fitted	

Miscellaneous

P1-3,5,6,8-14	Pins 2145	1 Pkt	(FL24B)
	DIL Socket 8 Pin	1	(BL17T)
	DIL Socket 16 Pin	1	(BL19V)
	PC Board	1	(GE06G)
	Constructors Guide	1	(XH79L)

PEAK/HOLD CIRCUIT PARTS LIST

Resistors: All 1% 0.6W Metal Film

R1	Not Fitted		
R2	Not Fitted		
R3	Fit Link		
R4	4k7	1	(M4K7)
R5	1k	1	(M1K)
R6	Not Fitted		
R7	Fit Link		
R8	Not Fitted		
R9	Not Fitted		
R10	Not Fitted		
R11	Not Fitted		
R12	Not Fitted		
R13	27k	1	(M27K)
R14	Not Fitted		
R15	10k	1	(M10K)

Capacitors

C1	Not Fitted		
C2,3	100μF 35V PC Electrolytic	2	(JL19V)
C4	2μ2F 100V PC Electrolytic	1	(FF02C)
C5,7	100nF Polyester	2	(WW41U)
C6	10μF 50V PC Electrolytic	1	(FF04E)
C8	Fit Link		

C9	Not Fitted		
C10	Not Fitted		

Semiconductors

IC1	Not Fitted		
IC2	LM13700	1	(YH64U)
D1	1N4148	1	(QL80B)

Links

LK1	Fitted
LK2	Not Fitted
LK3	Fitted
LK4	Fitted
LK5	Not Fitted

Miscellaneous

P1-4,6,7,9-15	Pins 2145	1 Pkt	(FL24B)
	DIL Socket 16 Pin	1	(BL19V)
	PC Board	1	(GE06G)
	Constructors Guide	1	(XH79L)

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LM13700(1) PCB **Order As GE06G Price £4.20**

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OCTAL RELAY BASES for sale, 20p each or 3 for 50p. Please enclose S.A.E. to R. Bennet, 4 Oak Road, Dibden Purlieu, Southampton, SO4 5PL.
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TELEQUIPMENT D52 OSCILLOSCOPE. Dual beam. Tel: (04862) 72120 (Woking Surrey).
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RS232/TTL CONVERTER

MARK II

By Chris Barlow

★ **Operates from Single +5V Power Supply**
★ **Meets all RS-232C Specifications**
★ **Normal or Inverse Logic**
★ **Two Drivers and Two Receivers**
★ **Onboard Voltage Quadrupler**
★ **±30V Input Level Protection**
★ **±9V Output Swing with +5V Supply**
★ **Low Power Consumption**
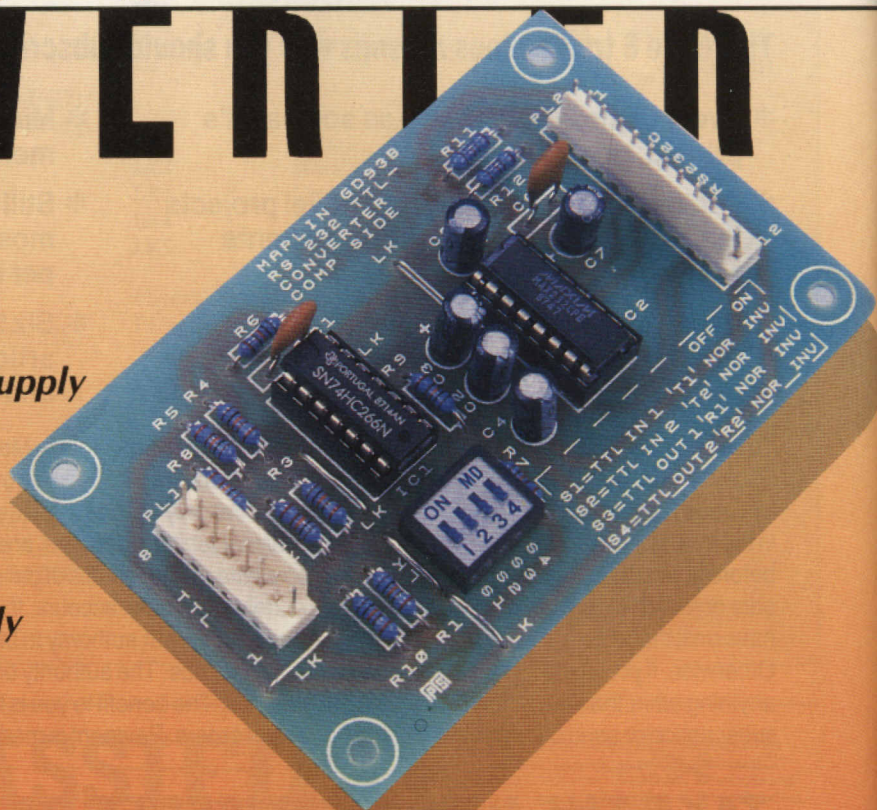
Introduction

Not all home microcomputers or peripheral devices have serial data signals at RS232C logic levels. A method of converting +5V TTL signals to RS232C levels (or vice versa) is needed and the converter module does just this. The original RS232/TTL converter by Dave Goodman appeared in the December 1983 issue of 'Electronics – The Maplin Magazine'. It offered a single RS232 input/output which was sufficient for most simple modems and data systems. However, as the sophistication of these peripheral devices increased the need to implement more of the RS232 control signals soon became apparent.

Specification of Prototype

Power Input:	+5V
Quiescent Current:	5mA
TTL Input Low:	<+2V
TTL Input High:	>+3V
	Max. +5V
TTL Output Low:	0V
TTL Output High:	+5V
RS232 Input Low:	<1.2V
RS232 Input High:	>1.7V
RS232 Maximum Input:	±30V
RS232 Maximum Output:	±10V Max.
	(Off Load)
RS232 Output Resistance:	300Ω
RS232 Output Short Circuit Current:	±10mA
Maximum Baud Rate:	19,200 Bd
Propagation Delay:	0.5µs
Instantaneous Slew Rate:	30V/µs
Transition Region Slew Rate:	3V/µs

The MAX232 Description

At the heart of the unit is the MAX232 IC which is a dual RS232 receiver/transmitter that meets all EIA RS-232C specifications while using only a +5V power supply. This significantly simplifies the system design by removing the need for power supply voltages other than +5V, the MAX232 has two onboard charge pump voltage converters which generate +10V and −10V power supplies from the single +5V power input, see Figure 1. The switching frequency of the converters is approximately 15kHz and this signal is generated by an internal clock. The first converter uses capacitor C3 to double the +5V to +10V, storing this voltage on the +V output filter capacitor C5. The second charge pump voltage converter uses capacitor C2 to invert the +10V to −10V and stores its voltage on the −V output filter capacitor C4. A small amount of power may be drawn from the +10V and −10V outputs to power external circuitry. The MAX232 contains four level translators. Two of the level translators are RS232C transmitters which convert TTL/CMOS input levels into ±10V RS232C outputs. The other two level translators are RS232 receivers, which convert RS232 inputs to +5V TTL/CMOS output levels.

The transmitters have a typical output voltage swing of ±9V when loaded with the nominal 5kΩ input resistance of an RS232 receiver. The output swing is guaranteed to meet the RS232/V.28 specification of ±5V minimum output

under the worst case conditions of both transmitters driving 3kΩ loads. The input thresholds are both CMOS and TTL compatible, with a logic threshold of about 25% of the +5V supply. An unused driver input can be left unconnected, for an internal 400kΩ pullup resistor holds the input high, forcing the transmitter output low (−9V). As required by the RS232 and V.28 specifications, the slew rate of the transmitters are limited to less than 30V/µs, limiting the maximum usable baud rate to 19,200 baud.

The receivers convert the ±5V to ±15V RS232 signals into +5V TTL/CMOS outputs. Since the RS232C/V.28 specifications define a voltage level greater than +3V as logic 0, the receivers are of the inverting type. The manufacture of the chip has set the guaranteed input thresholds to 0.8V minimum and 2.4V maximum, which are significantly tighter than the −3.0V minimum and +3.0V maximum required by the RS232C specifications. This allows the receivers to respond both to RS232 and TTL levels, with the inputs protected against overvoltage up to ±30V. The 0.8V lower threshold is important to ensure that the receivers will have a logic 1 output if the receiver is not being driven because the equipment containing the line driver is turned off or disconnected, or if the connecting cable has an open or short circuit.

The receivers have a hysteresis of approximately 0.5V, with a minimum guaranteed hysteresis of 200mV. This aids in obtaining clean output transitions, even
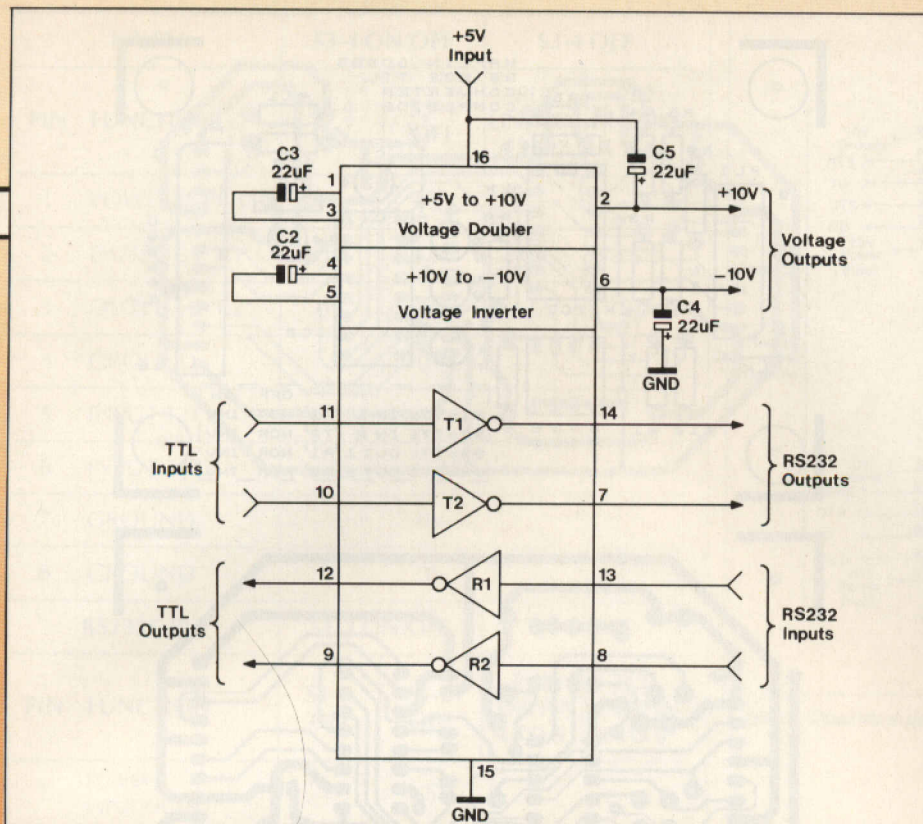
Figure 1. MAX232 Pin Configuration

Switch	Function		PL1 Pin	Off (Normal)	On (Inverse)
S1	TTL IN 1	'T1'	5	Non-Inverting	Inverting
S2	TTL IN 2	'T2'	6	Non-Inverting	Inverting
S3	TTL OUT 1	'R1'	2	Non-Inverting	Inverting
S4	TTL OUT 2	'R2'	3	Non-Inverting	Inverting

Table 1. Switch Positions

R5 on pin 5. The remaining resistors, R1, 6, 7 and R10 are used to pullup the second input of each gate, in this mode the NOR gates act as non-inverting buffers. However, if any of the control inputs are taken to ground (logic 0) that gate will now act as an inverting buffer. Four PCB switches have been included in the design to make this mode change as simple as possible. See Table 1.

PCB Assembly

The PCB supplied in the kit is a single-sided, fibre glass type, chosen for maximum reliability and stability. However, removal of a misplaced component is quite difficult, so please double-check each component type, value and its polarity where appropriate, before soldering! The PCB has a printed legend to assist you in correctly positioning each component, see Figure 3.

The sequence in which the components are fitted is not critical. However, the following instructions will be of use in making these tasks as straightforward as possible. It is usually easier to start with the smaller components. Begin with the resistors R1 to R12 saving the component lead off cuts, using six of these bend them to fit the link (LK) positions on the PCB.

Next install the PCB switch unit S1 to S4 ensuring that all four switches are in the OFF position. When fitting the IC sockets, make certain that you fit the appropriate holder in each position, matching the notch with the block on the legend.

The polarity for the electrolytic capacitors is shown by a plus sign (+) matching that on the PCB legend. On some capacitors the polarity is designated by a negative symbol (−) in which case the lead nearest this symbol goes away from the positive sign on the legend. The two disc ceramic capacitors, C1 and C6 are non-polarised so can be installed either way round.

When fitting the 'Minicon' connectors ensure that the locking tags are facing inwards. Finally, install IC1 and IC2

with slow rise and fall time input signals with moderate amounts of noise and ringing. The receivers have a propagation delay of 350ns for a negative going input signal and 650ns for positive going signals.

The 74HC266 Description

The +5V power supply de-coupling is provided by C7 with two 100nF disc ceramic capacitors, C1 and C6 providing additional high frequency de-coupling, see Figure 2.

The 74HC266 is a quad package Exclusive-NOR gate which has open drain outputs, for this reason resistors R3, 4 and R8, 9 are used as output pullups. Resistors R8 and R9 may be omitted if open outputs are required on the TTL pins 2 and 3 of PL1. The TTL inputs on pins 5 and 6 of PL1 also have pullup resistors fitted, R2 on pin 6 and
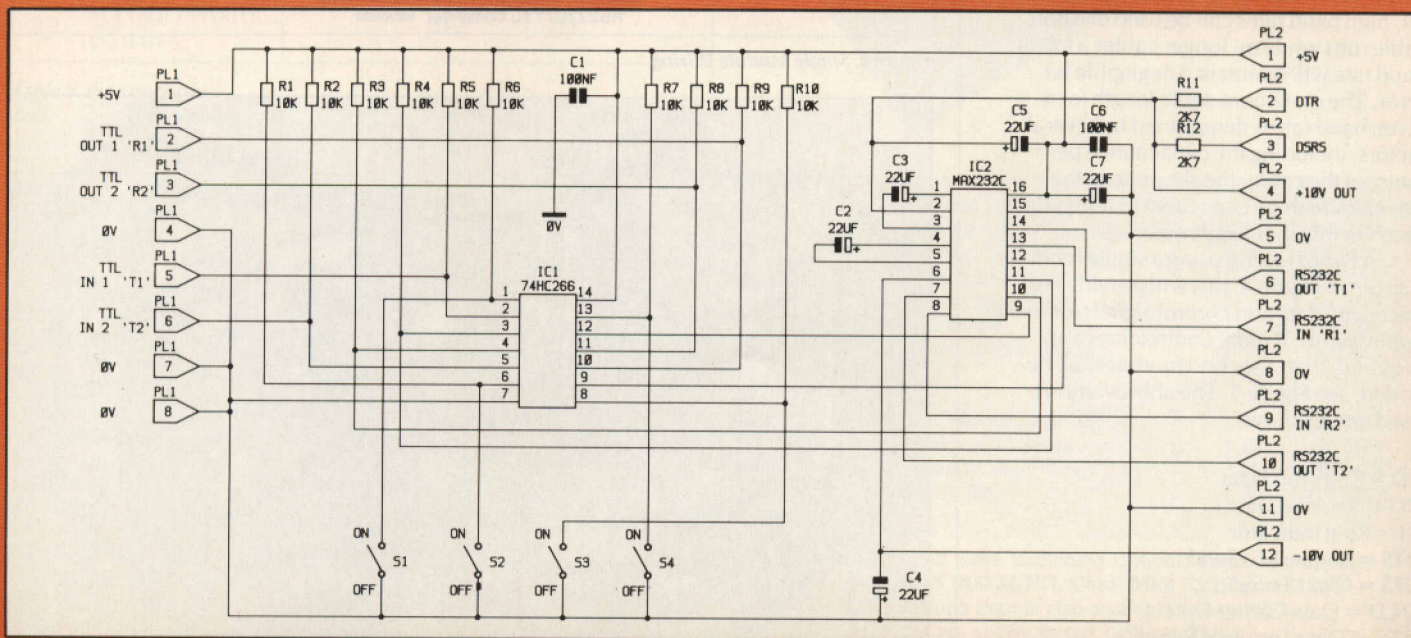

Figure 2. Circuit

making certain that all the pins go into their sockets and the pin one marker is at the notched end.

This completes the assembly of the PCB and you should now check your work very carefully making sure that all the solder joints are sound. It is also very important that the solder side of the circuit board does not have any trimmed component leads standing proud by more than 3mm, as this may result in a short circuit. Further information on soldering and assembly techniques can be found in the 'Constructors Guide' included in the kit.

Testing

All the tests can be made with a minimum of equipment. You will need a digital, or analogue multimeter and a regulated +5V power supply capable of suppling up to 100mA.

The first test is to measure the resistance on the power input pin of PL1. With the meter leads either way round on pins 1 and 8, a reading of greater than 500Ω should be present.

Next, select a suitable range on your meter that will accommodate a 100mA DC current reading and place it in the positive power line (pin 1 of PL1). Connect your +5V power supply and switch on, a current reading of approximately 5mA should be observed.

Now set your multimeter to read DC volts. All voltages are measured with respect to ground and should not exceed ±10V. When the unit is powered up the voltages present on the 'Minicon' pins of PL1 and PL2 should match the pattern shown in Table 2.

Wiring

The RS232 standard states that "The use of short cables (each less than approximately 50 feet or 15 metres) is recommended; however, longer cables are permissible, provided that the load capacitance does not exceed 2500pF". Baud rate and cable length can be traded off, high baud rates can be used on short cable runs while on longer cables a lower baud rate will maintain a negligible bit error. The maximum cable length for a given baud rate is determined by several factors, including the capacitance per metre of the cable, the slew rate of the driver under high capacitive loading, the receiver threshold and hysteresis.

A typical set up using a single module is given in Figure 4, this will provide the necessary data and control signals for most applications. If more control lines are required, then a second module may be added, see Figure 5. The abbreviations used are as follows:

TD = Transmit Data
RD = Receive Data
RI = Ring Indicator
RTS = Request To Send
CTS = Clear To Send
DCD = Data Carrier Detect
DTR = Data Terminal Ready
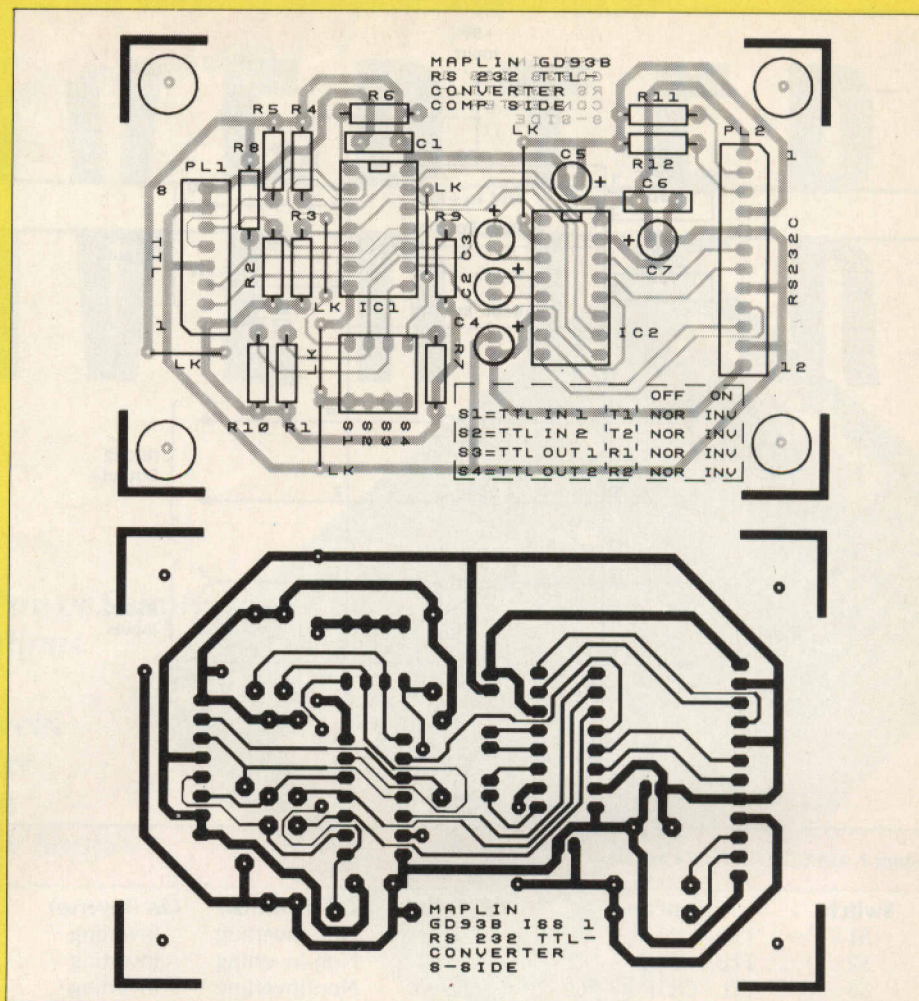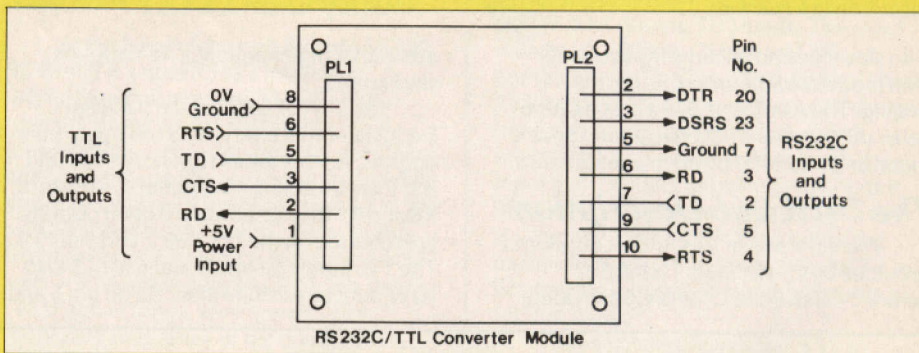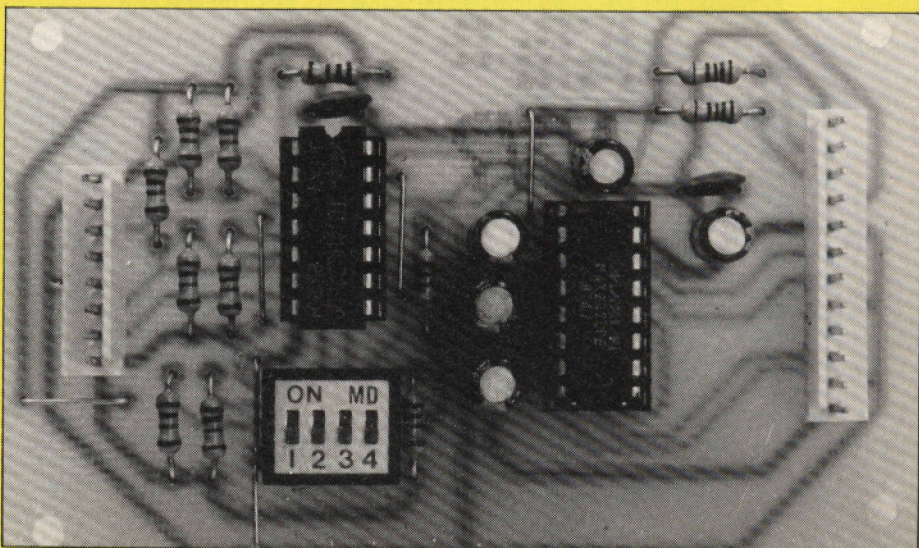**DSRS** = Data Signal Rate Select

Figure 3. PCB Layout

Figure 4. Single Module Wiring

View on the PCB.

TTL PL1		S3-4 ON/OFF		S3-4 OFF	
PIN	FUNCTION	S3-4 ON	S3-4 OFF	PL2 LINK PIN 4 TO 7	PL2 LINK PIN 4 TO 9
1	POWER INPUT		+5V		
2	OUTPUT 1 'R1'	0V	+5V	0V	+5V
3	OUTPUT 2 'R2'	0V	+5V	+5V	0V
4	GROUND		0V		
5	INPUT 1 'T1'		+5V		
6	INPUT 2 'T2'		+5V		
7	GROUND		0V		
8	GROUND		0V		

RS232C PL2		S1-2 ON/OFF		S1-2 OFF	
PIN	FUNCTION	S1-2 ON	S1-2 OFF	PL1 LINK PIN 4 TO 5	PL1 LINK PIN 4 TO 6
1	POWER INPUT/OUTPUT		+5V		
2	DTR		+10V		
3	DSRS		+10V		
4	VOLTAGE DOUBLER OUTPUT		+10V		
5	GROUND		0V		
6	OUTPUT 1 'T1'	+10V	−10V	+10V	−10V
7	INPUT 1 'R1'		0V		
8	GROUND		0V		
9	INPUT 2 'R2'		0V		
10	OUTPUT 2 'T2'	+10V	−10V	−10V	+10V
11	GROUND		0V		
12	VOLTAGE INVERTER OUTPUT		−10V		

Table 2. Pin Functions
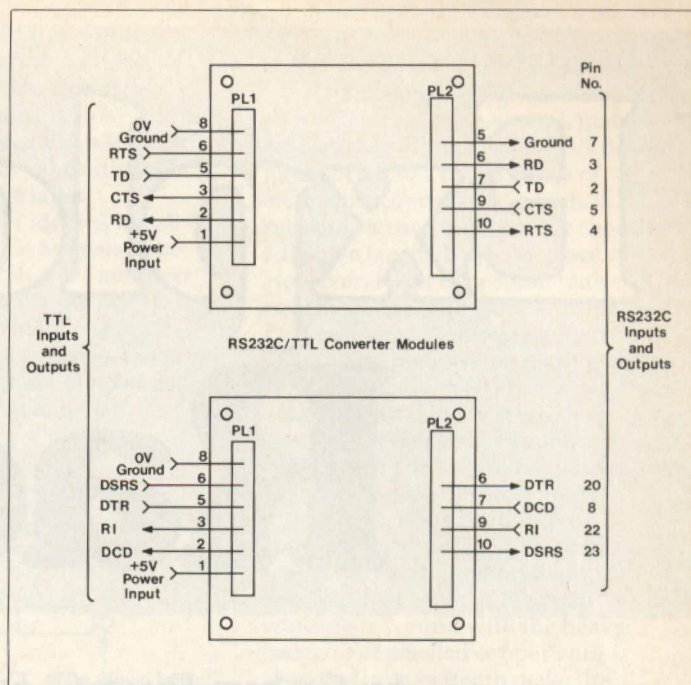
Figure 5. Dual Module Wiring
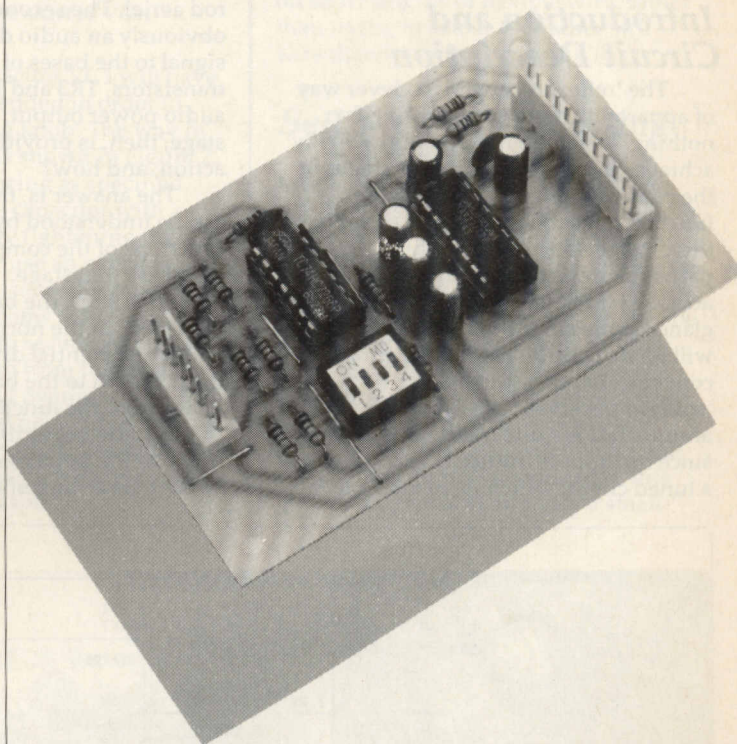
RS232/TTL CONVERTER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film
R1-10	10k	10	(M10K)
R11,12	2k7	2	(M2K7)

CAPACITORS
C1,6	100nF Minidisc	2	(YR75S)
C2,3,4,5,7	22μF 16V P.C. Electrolytic	5	(FF06G)

SEMICONDUCTORS
IC1	74HC266	1	(UB71N)
IC2	MAX232C	1	(FD92A)

MISCELLANEOUS
S1,2,3,4	DIL Switch SPST Quad	1	(FV43W)
PL1	Minicon Latch Pl 8W	1	(YW13P)
PL2	Minicon Latch Pl 12W	1	(YW14Q)

Minicon Latch Housing 8-Way	1		(YW23A)
Minicon Latch Housing 12-Way	1		(YW24B)
Minicon Terminals	2 Pkts		(YW25C)
DIL Socket 14-pin	1		(BL18U)
DIL Socket 16-pin	1		(BL19V)
P.C. Board	1		(GD93B)
Constructor's Guide	1		(XH79L)

OPTIONAL
Threaded Spacer M3	1 Pkt		(FG38R)
Isobolt M3 x 6mm	1 Pkt		(BF51F)
Isoshake M3	1 Pkt		(BF44X)
Isonut M3	1 Pkt		(BF58N)

A complete kit of all parts, excluding Optional items, is available:
Order As LM75S (RS232/TTL Conv Mk2 Kit) Price £12.95
The following item is also available separately,
but is not shown in our 1989 catalogue:
RS232/TTL Converter PCB **Order As GD93B Price £2.50**

Exploring Radio

by Graham Dixey C. Eng., M.I.E.R.E.   Part 7

Introduction and Circuit Description

The 'reflex' receiver is a clever way of apparently getting something for nothing! What the reflex action actually achieves is to make one of the stages of the receiver perform two separate functions in sequence. In the case of a three-stage receiver, as in this particular design, it behaves as if it actually had FOUR stages. A quick glance at the circuit diagram of Figure 1 will identify quite readily the three conventional stages of a TRF or 'straight' receiver. The first stage built around TR1 is quite clearly an r.f. stage, since its input is inductively coupled to a tuned circuit which is, in fact, a ferrite rod aerial. The second stage, TR2, is obviously an audio driver supplying a signal to the bases of the output transistors, TR3 and TR4, in the final, audio power output, stage. Which stage, then, is providing the reflex action, and how?

The answer is, the first stage, and it can be understood by considering the functions of the components that comprise that stage.

For a start, the base bias for TR1 is provided, in the normal way, by the resistive potential divider, R1 and R2, the d.c. path to the base of the transistor being from the junction of R1 and R2 through the negligible resistance of L2. Resistor R3, bypassed by C4, is also part of the bias arrangement, again quite conventional. But what of capacitor C3 and diode D1, and which component in the circuit forms the collector load; is it L3 or RV1? The clever answer is, that it is both! This is where the reflex action arises.

The modulated AM signal, coupled into the base of TR1 by L2 after being tuned in by L1 and VC1, is amplified by TR1, the amplified signal being developed across the r.f. choke L3 (which has a high reactance at radio frequencies); none of this signal is developed across RV1 since the latter is bypassed by C5 (low reactance at radio frequencies). The amplified r.f. signal is now passed through the low reactance (at radio frequencies) of C3 to the diode D1 which acts as a diode detector. The
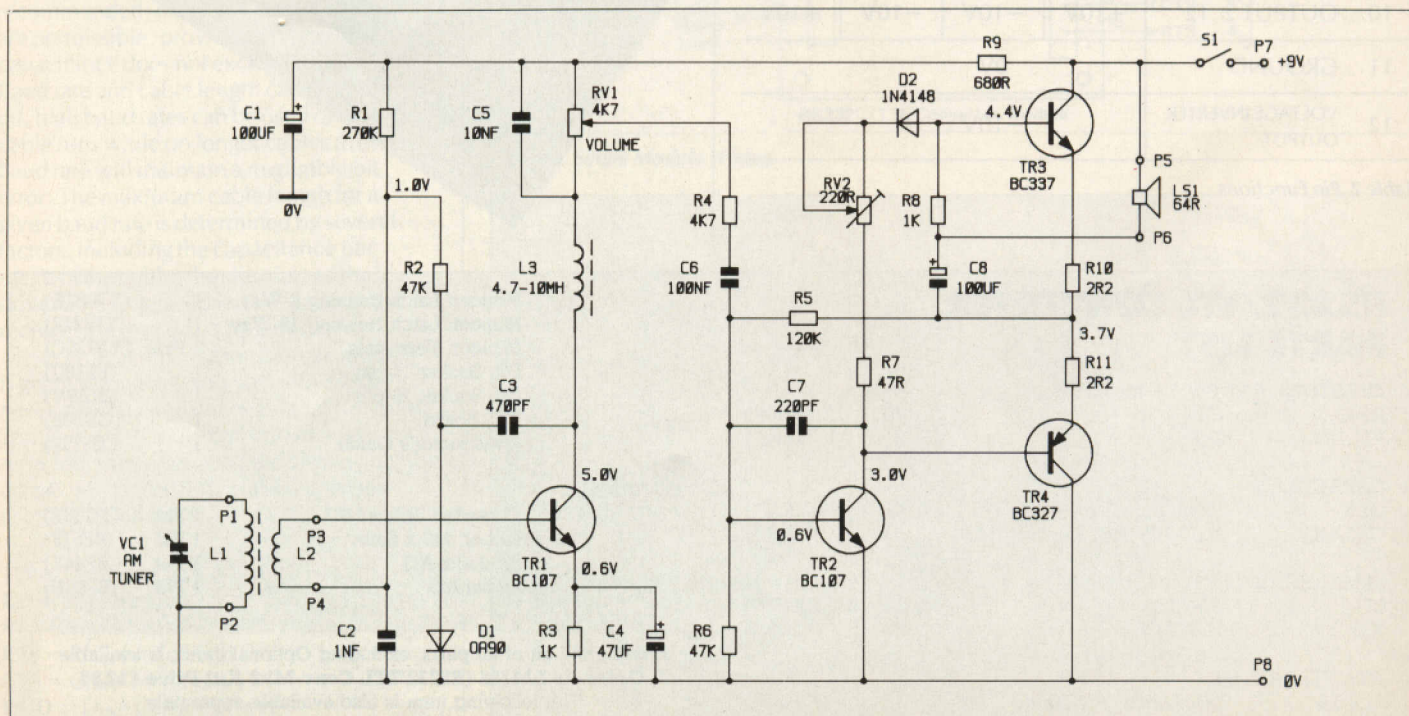

Figure 1. Circuit of the receiver.

combination R1 and C2 form the time constant for the diode detector so that the recovered audio signal now appears across C2, the latter having a fairly high reactance at audio frequencies. Since all of this is taking place in the input circuit of TR1, the latter now acts as an amplifier again, but this time for the audio signal. This second time round (so to speak), the collector load is RV1. This is because L3 has a low reactance at audio frequencies while C5 has a high reactance - the very opposite of the case when we were considering the r.f. signal.

The potentiometer RV1 is, of course, the volume control so that any desired proportion of the audio signal can be tapped off and fed to the audio stages. RV1 is decoupled by C5, the latter forming a high-pass filter with R4, to remove any residual radio frequency voltage.

The above description shows that TR1 is operating both as a radio-frequency amplifier and as an audio-frequency amplifier, the actual function of the stage relative to the signal being automatically determined by the frequency-conscious nature of some of the components, notably L3, C3 and C5. The audio output voltage from this stage is more than capable of driving the output stage to full output in areas of good reception.

From the volume control onwards the circuit is fairly conventional. Capacitor C6 couples the audio to the base of the driver TR2. Bias for this stage (with d.c. and a.c. negative feedback) is provided by R5 and R6. The preset RV2 is used to set the standing current in the output stage (described later). The power output capability is not very great but is more than adequate for a small personal receiver and, in areas of good signal strength, will certainly require the volume control to be turned down! Because of the relatively high output impedance of the complementary output pair, TR3 and TR4, a 64 ohm miniature speaker is used.

Construction of the Receiver

The availability of a custom PCB makes this a straightforward project and one that a beginner can tackle with complete confidence, given some previous experience in clean and neat soldering and the ability to identify the various components correctly. While there is no actual kit of parts, all components required are available from Maplin and most are fairly non-critical anyway. For example, while the first stage, TR1, is specified with a BC107, there is no reason why a BC109 should not be used instead; in fact the extra gain may be useful in lower signal strength situations.

One component that can be difficult to find these days is the r.f. choke. However, a Maplin component

(in fact a miniature 4.7mH r.f.c.) is available - see Parts List. One minor word of caution if ordering this component; it looks just like a slightly tubby 4.7k 5% resistor - including all the colour bands of the latter component! So, if after identifying all other parts, that is what appears to be left, then that is your choke! I mention this because traditionally the wave-wound type of choke identifies itself quite readily whereas the appearance of this particular component, if taken out of context, is actually somewhat misleading.
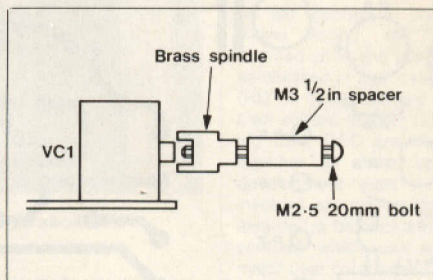

Figure 2. Extending the shaft of VC1.

The tuning capacitor VC1 will have to have its shaft extended in order to take a normal tuning knob. The way in which this is done is shown in Figure 2, the required parts being as specified. Grip the shaft of the capacitor with pliers while carefully tightening the screw and DO NOT use an over-length screw for this or the capacitor may be damaged. If there seems to be insufficient thread to secure the spacer, file a millimetre or so from the length of the spacer but do not overdo it.

There should be no real problems with the PCB construction if normal care is taken. The fully assembled PCB is shown in Photograph 1.

The Ferrite Rod Aerial

The main winding, L1, consists of about 55 turns, close-wound, that is adjacent turns touching. In this design I have specified a heavy gauge of enamelled copper wire, as this is self-supporting and does not need any adhesive tape to hold it in place. However, it can be wound, with equally good results, using ordinary PVC insulated stranded equipment wire, using pieces of insulating tape to secure the ends. A few turns, say three, wound around the first winding, at the 'earthy' end, forms the coupling coil L2. This can also be secured with insulated tape. In my own design, shown in Photograph 2, the coupling coil is secured by twisting up its lead-out wires and sliding a short length of PVC sleeving over them. If the main winding is wound with the heavy gauge of enamelled copper wire specified, it is better to make the connections to it by cutting and scraping the ends clean and soldering on short lengths of flexible wire, rather than trying to solder the rather stiff wire directly to the PCB pins.

Setting Up and Testing

Assuming that the PCB is fully assembled (and checked carefully for dry joints, shorted tracks, etc.), and the connections to the aerial, speaker and battery have been made, the moment of truth has finally arrived! Before switching on, the preset RV2 should be rotated to the fully anti-clockwise position. A milliammeter, on the 100mA range, should be connected in series with the positive supply lead. With the power now switched on, but the volume control at minimum, this meter will probably indicate a small

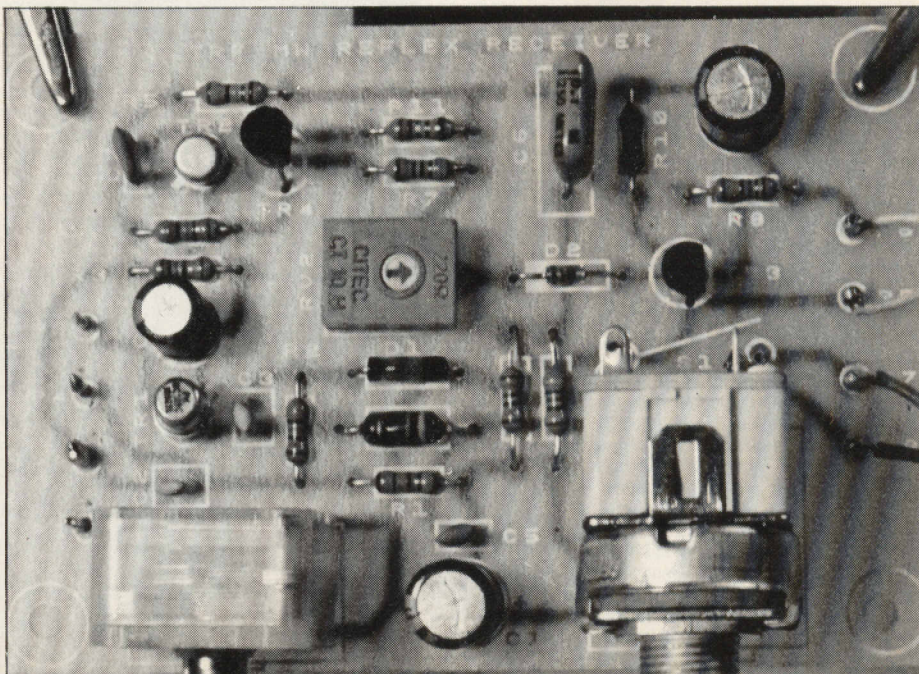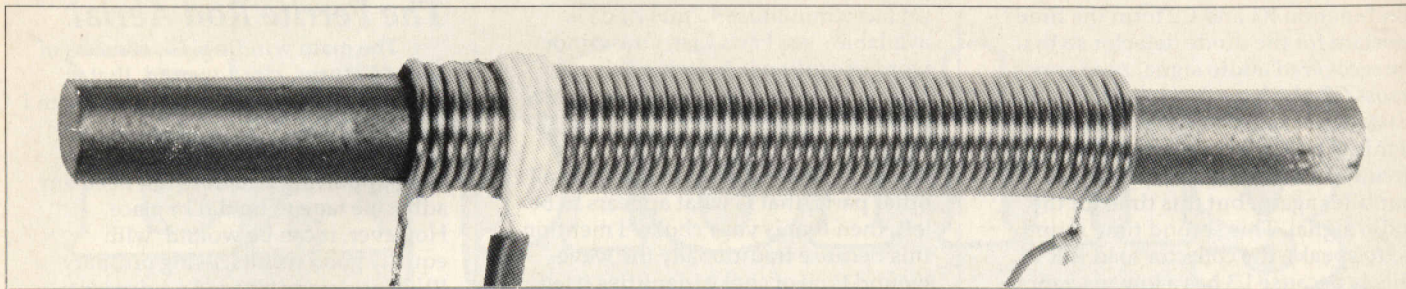*Photo 1. The fully assembled PCB for the reflex receiver.*

Photo 2. The ferrite rod aerial for the receiver. Note the neat appearance obtained by winding L1 with heavy gauge E.C. wire. L2 consists of three turns of flexible equipment wire held securely with a piece of sleeving. Flexible wires are used for lead-outs for L1.
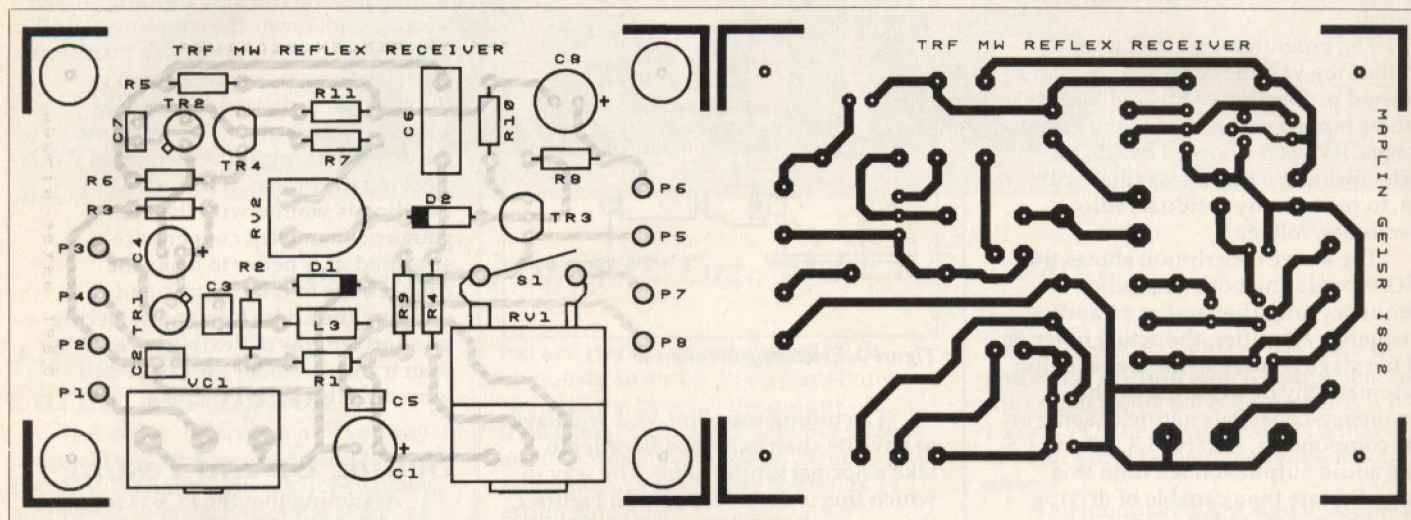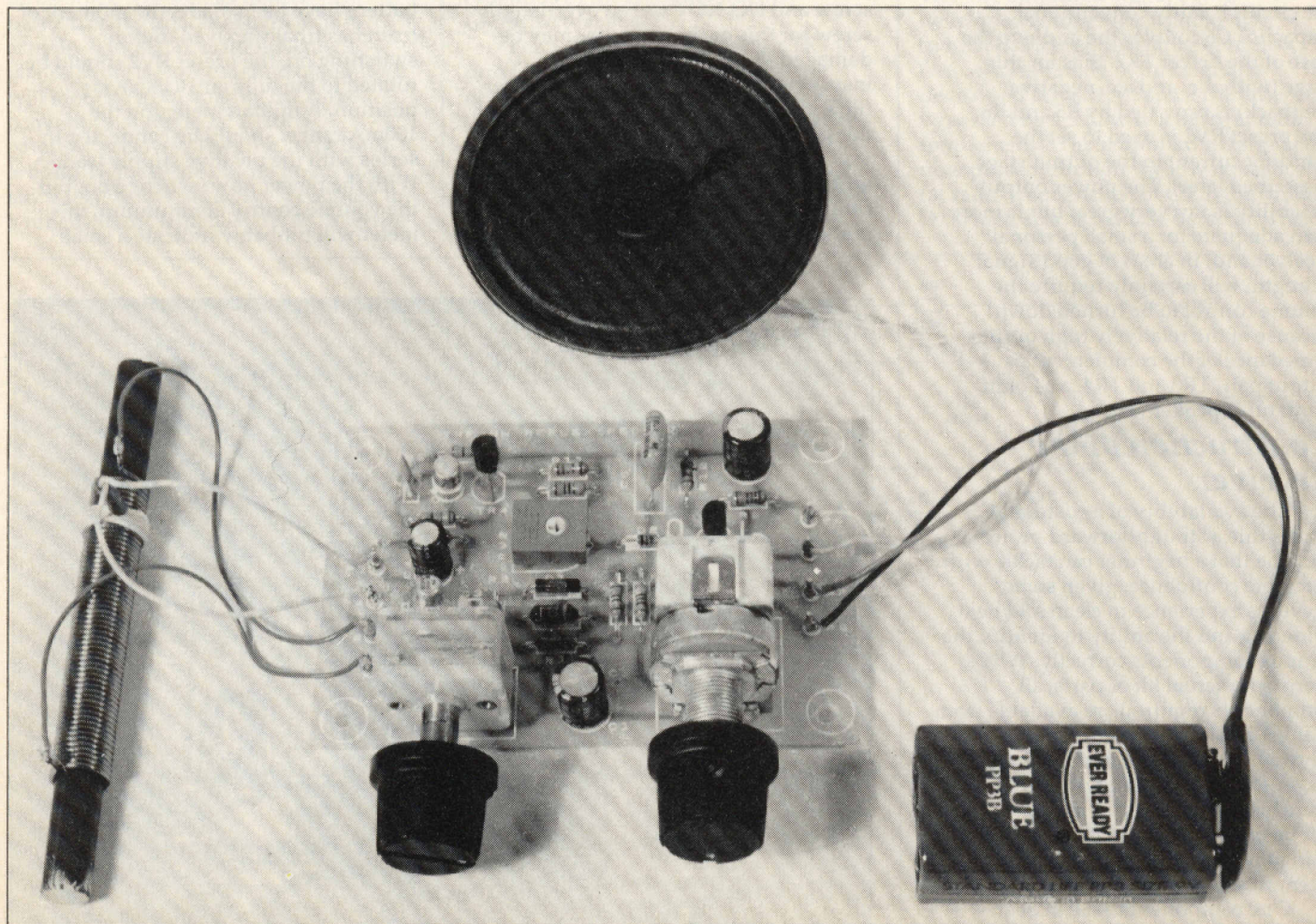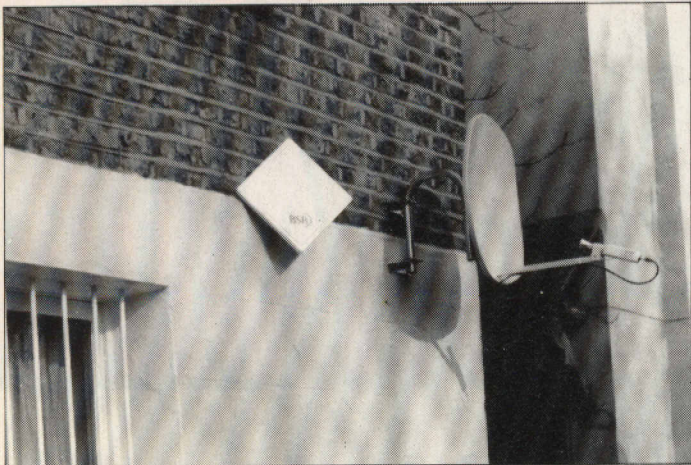

Figure 3. PCB track and legend.

Photo 3. The fully assembled TRF reflex receiver.

NEWS REPORT

The squarial receiving BSB and a Grundig 60cm offset parabolic dish receiving Astra.

Pictures From Space

One of the biggest revolutions in broadcasting has just hit the UK, Satellite TV. Although the reception of satellite TV pictures is not new, it has up to now been out of reach of a lot of people. The previous generation of satellites were equipped with low power transmitters (20W) and could only be received using large (1 to 1.6 metre) dishes, the cost of the equipment was in the order £1,000 plus, for a remotely steerable system (the steering system allows the dish to be re-aligned to a different satellite). With the newer generation of satellites, equipped with higher power transmitters, reception will be possible using much smaller dishes (55 to 80cm) or even using the flat 25cm 'Squarial' publicised by BSB. The competitors in the UK market, Astra and BSB are each fighting to win support of the public. At Maplin, we shall keep you up to date with news of developments and

give unbiased information on technical superiorities or shortcomings. A recently released report by 'Logica' entitled 'Satellite Television Receivers – The European Market', reveals that the predicted (cumulative) sales of individual satellite receiver systems in the UK, will be between 80,000 to 170,000 systems by the end of 1989 and 6 to 8.5 million by the end of 1996. The report suggests that Satellite Television Receivers (STR's), will be priced at £250 for PAL receivers, rising to £300 with the introduction of PALCRYPT encoded transmissions. This price should drop to around £130 by mid 1992. ASTRA will be transmitting in the PAL format, whilst BSB will use D-MAC. To enable subscription fees to be levied, transmissions may be encoded, there are three encryption standards; PALCRYPT, EUROCYPHER and EUROCRYPT, these encoding systems would be used to prevent unauthorised reception of broadcasts.

Dotty Displays

Panasonic announce the state of the art in information display modules. The 16 x 16 dot matrix modules have been designed using the very latest ASIC chip technology driver circuits. They are constructed using surface mount technology and contain fewer components so as to be more compact and price competitive than conventional

boards. The modules are available in 3, 5 and 8mm LED dot sizes. The Panasonic dot matrix displays are capable of running at video speeds (20MHz) and are available in mono and tricolour combinations for customised applications. The displays can be used to show text and graphics, and potential markets include display panels in shopping arcades, sports arenas, production lines and airports or stations.
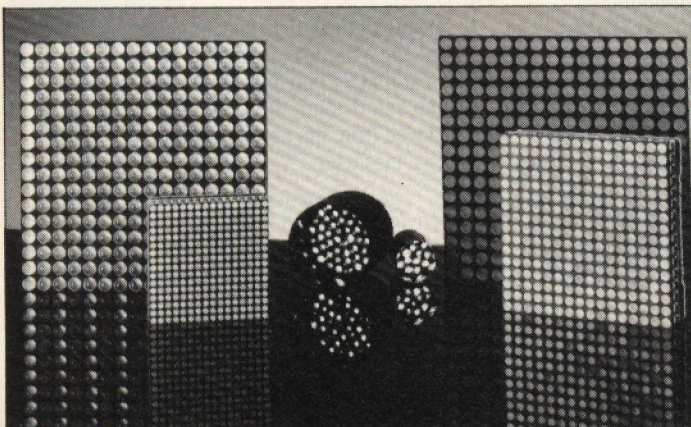
State of the Art Information Display Modules.

UK Frequency Allocation Chart

The radio frequency bands allocated to amateur, commercial and industrial users in the UK can be seen at a glance on a colour coded bar chart prepared by the DTI's Radio Communications Division and published by HMSO. Frequencies from 1kHz to 60GHz are covered by the chart, which is divided into primary and secondary users. The main users shown are broadcasting, fixed services, mobile, amateur, meteorological, radio location, navigation, astronomy, space, and various maritime, aeronautical and satellite bands. The 'United Kingdom Radio Frequency Allocations Chart' is published by HMSO, ISBN 0 11 514637 7, price £2.50. Enquiries; Tel. 01 215 4751.

More On HDTV

As we reported in the last issue of 'News Report', the US is getting alarmed about the possible lead being established in high definition television (HDTV) by Europe and Japan. No less than sixteen leading US firms, including IBM, DEC and Apple have got together to draw up a business development plan. The companies involved are hoping that they will be awarded a broadcast channel service contract which can be licensed to major user companies.

Quantum Leap For TI

Having highlighted the Texas Instruments introduction of the world's fastest programmable logic device in our last issue, TI is now claiming a world first in Quantum Tunnelling Transistors in Gallium Arsenide. This is not a method of speeding up the construction of the Channel Tunnel, but a quantum leap in transistor technology. With critical dimensions 100 times smaller than conventional transistors, the device operates on fundamentally different principles, known as quantum mechanical effects, which dominate the behaviour of matter and energy at dimensions of 0.02 micron (20 billionths of a metre) and below. Still at present a laboratory development, future chips incorporating quantum effect transistors might contain 100 times more functions in the same space and consume far less power than today's devices. One day, says TI we might see a laptop supercomputer that runs on flashlight batteries!

IBM Breaks The Chip Speed Record

More world speed records have been broken by IBM, who have developed Complimentary Metal Oxide Semiconductor (CMOS) circuits with parts that are 300 times thinner than a human hair – only one quater of a micron wide. A micron incidentally is one millionth of a metre. The transistors used in the IBM circuits can switch on and off some 30 billion times a second. As a result, logic chips in the 90's could have about 1 million logic circuits compared to 100,000 today. In computer memory terms, such small dimension quarter micron transistors will make possible CMOS memory chips with a capacity of 256 million bits of information.

Getting The Picture

A method of sending frozen TV pictures by facsimile has now been developed by Eltime Vision Systems. The system interfaces video, fax and computing technologies. The Videofax which has been tested on such equipment as IBM, Cannon, Amstrad and Olivetti PCs, makes use of a video

camera and monitor. Eltime believes that the system has great potential in medical operations, perhaps transmitting X-Ray plates, for research purposes and to assist maintenance and security procedures.

Meanwhile, the much heralded videophone – a method of capturing still images which can then be transmitted by the public telephone network to a remote destination. Several systems have been submitted for PTT approval, including the Panasonic WG-R2 visual telecommnications unit, which is expected to be marketed at about £200. However, the respective marketing teams could face the same initial problems faced by Bell. How do you make the first sale when no one else has the facility?

'Electronics' suggestion: market twin systems in the same package.

Global Network

Progress, it seems, is being made in establishing a single international video communications standard – but don't hold your breath yet. According to GPT Video Systems, the aim is to enable the user to interconnect his video equipment with anything from a videophone to a large scale videoconference system. So far creating the standards has involved over 100 man-years of research since 1983. The new recommendations are due to be approved by the CCITT in 1990, but it is unlikely, says GPT, that any products will emerge into the market place before 1991 at the earliest. High Tech does not always mean Fast Tech it seems.

Getting The Right Number

That extra digit to be added to London telephone numbers, which we revealed in the last issue, looks like being 070 or 081. A decision apparently has to be made soon if London is not to run out of phone numbers. Meanwhile, more changes are on the way if the Brussels Bureacrats have their way. The plan is to standardise emergency telephone numbers throughout Europe. The days of 999 could be numbered. But on a more practical note, did you know that BT operates a special 'midnight line service' which allows free calls within the UK. The snag? The quarterly rental is £200.

Box Clever

Vanderhoff Buisness Systems has now introduced a Smart Box which will allow multi line users to switch from BT to Mercury for long distance and international calls. Operating savings of between 10 and 15% can be achieved. The cost of the Smart Box is £200 and there is an annual subscription of £8. The price sets this unit aside for medium to heavy users of long distance communications.

Sign In Please

ROCC Patern Recognition has produced a technology which accurately differentiates between true and false signatures. For all practical purposes, signatures can now be electronically verified for personal identification and authentication. The system works by deriving a numerical code from a minimum of six sample signatures. The numerical code is then either printed alongside the signature box on a cheque or encoded in the magnetic strip on a plastic credit or identification card. The company claims that the system is around 95% accurate in dealing with forgeries where the forger has not seen the true signature.
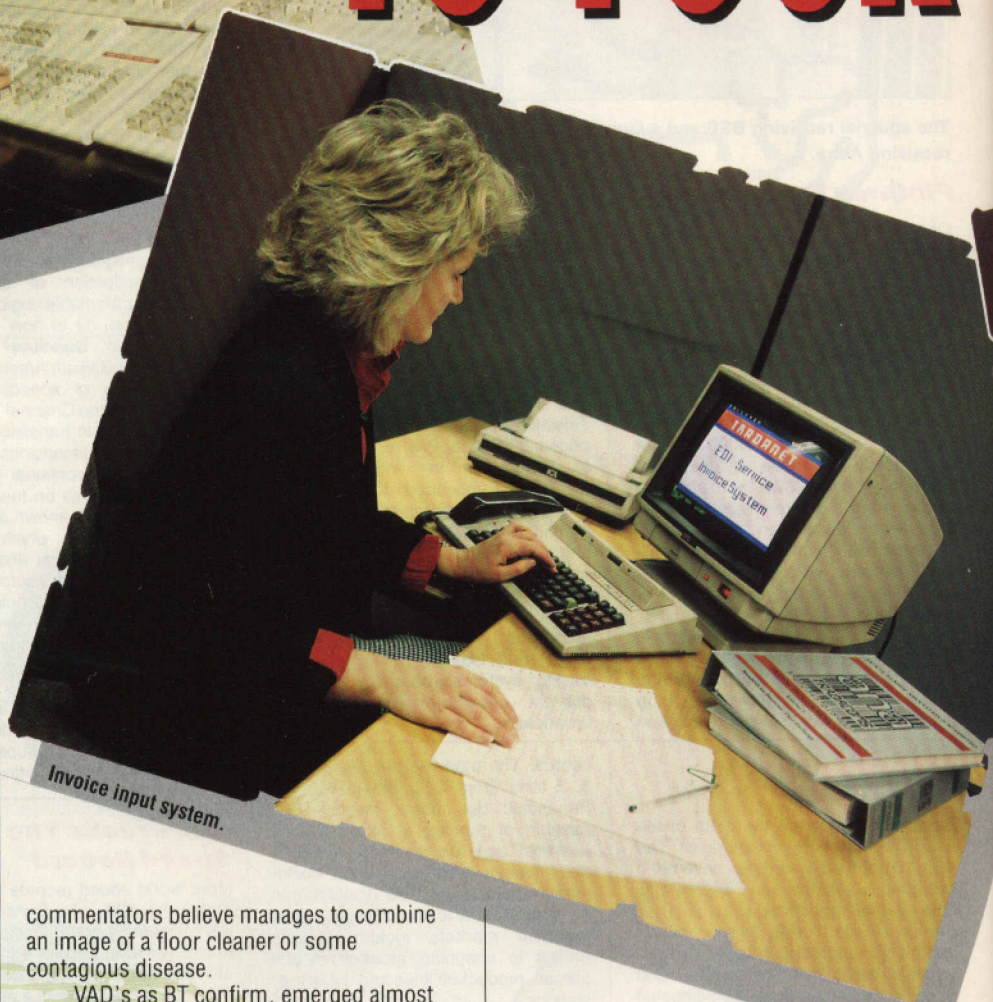
ADDING V
TO YOUR T

The computer data centre at Bletchley.

Invoice input system.

by Alan Simpson

There must be something perverse about an industry which insists on sticking unintelligible labels on to new levels of technology. Such is very much the case with VAD, which even when translated probably leaves much to be desired. VAD's, or Value Added Data Networks have been defined by no less an authority than Michael Naughton, who heads the consultancy Applied Network Research, as being the adding of extra value to the national telephone service.

Never slow to hedge their bets British Telecom presents two definitions. "A VAD adds value to raw data" and the even less wholesome "The manipulation of information". However BT obviously spent some additional time thinking the matter through - or hired a new copy writer - and came up with a fully comprehensive definition, "A VAD is a telecom service which can be said to add value if it offers the user something beyond the point-to-point transmission and switching of voice or data". Therefore, both BT's Prestel viewdata service and Telecom Gold electronic mailboxes are VAD's because they interconnect computers via the telephone network and supply a range of information, banking, shipping and electronic mail services.

Confusion however does not rest solely with British Telecom. It took the Department of Trade & Industry several years to come up with the term VANS (Value Added Network Services). They then discovered they had got the name wrong and it was back to the terminology drawing board before emerging with VAD's - a name many network industry commentators believe manages to combine an image of a floor cleaner or some contagious disease.

VAD's as BT confirm, emerged almost as a by-product of the Information Revolution. It was, it seems, a case of a close encounter of the computing and telecommunication kind. Not that BT is complaining. There are already more Telecom Gold mailboxes registered in the UK than there are telex subscribers. This is perhaps only to be expected as telex are normally limited to just a few per organisation while mailboxes could be distributed to many users. The DHSS alone claim to have some 5000 Gold mailboxes.

A History of VAD's

It was BT who launched what is generally regarded as the world's first Value Added Network, PRESTEL in 1979. This provided access to an information service by means of the public telephone network, a TV set and a home computer. But it soon became clear that BT had chosen the wrong target, and before long, the marketing thrust was moved from the home user to that of the business user.

VAD's have a particularly short history arriving a year after PRESTEL had been introduced. The DTI issued its first VAD licenses in October 1982 and early operators included AGB Cable & Viewdata, the SWIFT banking network, the airline SITA system and Midland Bank's Travinex travel service as well as, of course, BT's viewdata service. Computer bureaux selling computer time can also be counted as early VAD suppliers. Many such bureaux make use of Packet Switch

VALUE TELEPHONE

A Mezza computer station.

Telecom Gold.

Stream networks in order to provide fast and easy access to a central computer or to act as an interface to a more remote computer installation.

It was generally agreed that the format of the original licence was over rigid, attempting to embrace everything from system interfacing to network support and management. As a result the DTI, prompted no doubt by governments liberalisation policies, relaxed the rules as a means of encouraging the growth of VAD's.

In particular, the new rules attempted to define the role of the telephone network carrier – at present limited to British Telecom, Mercury Communications and the independent Hull (now Kingston) Telecoms,

plus the Cellnet and Vodafone cellular radio networks. The DTI also defined the role of the non-carrier network suppliers, such as IBM and ICL (part of STC) together with the increasing number of specialist groups providing financial information services. At the same time the government announced that no further carrier licences, domestic or international, would be issued before 1990.

In the US however, free networking competition flourishes. The privately owned telephone companies have long been permitted to lease lines for the transmission of computer data to anyone who is prepared to pay for the facility. In many cases, those leased lines were then used to provide specific services to users which were not available from the main telephone service suppliers.

UK regulations are expected to move towards the US system at which time it will become possible for users to rent, lease or

resell telephone lines from carriers. At this point, telecom networks may not need to add value to the services being made available. Looking even further ahead, total deregulation could be on the UK cards.

As a result of this encouragement, UK network service revenues are expected to grow by a factor of 15% per month to over £1000m by 1991. One year later when the European trading barriers are due to be lowered, VAD operations are forecast to escalate. With several European countries moving towards partial deregulation of their telecom monopolies, VAD's are set to become a major feature of European telecoms operations.

International VAD Assignments

Although the government has signed agreements between the UK, the US and Japan which allows private operators to compete with public international carriers for the provision of VAD's using private leased lines, many industry observers fear that Japan could dominate world markets if given half a chance. Already the Japanese VAD market is by far the fastest growing sector in Japan, but such UK operators as ISTEL, who are providing Electronic Data Interchange (a service which supposedly eliminates much of the current company paperchase mountains) between car plants in the UK and Japan, and INS Tradanet who are providing international links into the US and Japan, are capturing some of the VAD action.

According to British Telecom, the potential variety of VAD operations and

services is limited only by human imagination. With VAD operations benefiting from the steady introduction by national and international carriers of ISDN (Integrated Service Digital Networks) services such as Electronic Fund Transfer and Point of Sale can be expected to show considerable growth.

Vanguard Set the Awareness Scene

Towards the end of 1986 the government funded a VAD awareness campaign called VANGUARD. This was sponsored by such mega VAD players as BT, IBM, INS, ISTEL and a leading clearing bank. This group incidentally collectively controls most of the UK private and public networks services. It was ANR's Michael Naughton - who the industry is tipping to be voted "VAD personality of the year" - that was responsible for getting the DTI Vanguard initiative up and running. Since the launch, Michael Naughton estimates that the awareness of VAD's among senior company management has risen by over 40%.

No review of comms technologies is complete without some reference to standards. The European Commission is keen to see comms standards agreed and the integration of a full scale information service market. The chosen standard is OSI (Open System Interconnection) with the IBM proprietary standard SNA (Systems Network Architecture) providing positive interface.

The Players

Not so much a major player but more the captain of the team, BT who through its Dialcom Group operation, have pin-pointed three major user areas: EDI, Electronic Messaging and on-line information databases. A somewhat wider view is taken by IBM who could well qualify as the team vice captain. The IBM Managed Network Services embrace a host of VAD operations including links to the Cellnet and Vodafone cellular networks.

Digital Equipment, also jockeying for a top player role, are hoping to dominate the VAD financial operations arena. A further keen player is Midland Bank whose FASTRAK VAD service aims to provide their subsidiary Thomas Cook with some 4000 travel outlets over the next few years in addition to supplying such financial services as home banking.

FASTRAK in effect piggy-backs on the banks' own extensive nationwide network using spare capacity. Let's hope that this spare capacity doesn't become stretched and priorities have to be given to the bank over VAD operations. Otherwise we could find ourselves having to wait longer at the local travel agency to confirm our bookings. Further members of the players team include the McDonnell Douglas/GEISCO partnership, INS and ISTEL.

According to Michael Naughton, main users of VAD's are likely to come from banking, insurance and finance sectors. Other targeted activity areas spotlighted by Michael Naughton include manufacturing, textiles and clothing, wholesale food and distribution, local government, construction and transport. In fact any company with a heavy messaging traffic requirement or needs frequent on-line access to an industry or general information database.

Into the VAD Future

For us end users, the most visible sign of VAD operations are such network activities as credit card authorisation systems and travel reservation procedures. But before long, we can expect to see developments which enable the linking of PC's to a VAD network, not just for PRESTEL but access to corporate databases, plus electronic mail links to telex and facsimile.

But it is not all good news for the VAD movement. The Federation of Microsystems Centres who have upwards of twenty local business centres, have moved out of BT Gold into BT facsimile. With fax equipment costs falling, the Group are finding it more cost effective to zapp messages around their centre network by fax rather than electronic mailboxes.

ELECTRONICS BY EXPERIMENT

Part 7 by Graham Dixey C.Eng., M.I.E.R.E.

Introduction

The previous article in this series dealt with the basic principles of the operational amplifier and discussed some of its basic 'configurations'. In this article we shall look at a small but useful, as well as interesting, selection from the wide range of applications that it can be used for.

As a Pulse Generator

It is possible to make the Op-amp generate square waves using just four extra components, three resistors and one capacitor. This type of circuit is a form of 'relaxation oscillator' known more commonly as an 'astable multivibrator'. Its circuit is shown in Figure 1. R1 and C1 form a RC time constant that determines the frequency of oscillation. The pair of
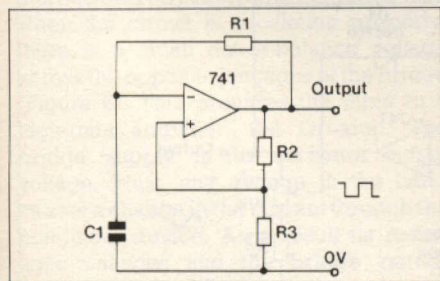

Figure 1. Astable multivibrator.

resistors R2 and R3 form a potential divider across the output, so that whatever the potential (and polarity) of the output voltage at any instant, the voltage fed back to the non-inverting input will be a given fraction of it; for example, if R2 was 9k and R3 was 1k, then 1/10 of the output voltage would be applied to the non-inverting input. With this type of circuit the output voltage is always either near to the positive supply voltage value (known as positive saturation) or the negative supply voltage (known as negative saturation). At the same time, the voltage on the inverting input will always be varying, since it is some point on the curve of voltage/time as the capacitor is charging either towards the positive supply voltage or towards the

negative supply voltage. Thus the circuit operates as follows.

Suppose that the capacitor is at this moment uncharged and that the output is in positive saturation (i.e. close to the positive supply voltage, V_s). The voltage at the inverting input is 0V while that at the non-inverting input is a positive voltage whose magnitude is determined by the values of R2 and R3; suppose that these are 9k and 1k as suggested just now. Suppose also that the output voltage is +14V. Then the voltage at the non-inverting input will be 'one tenth of this value', i.e. +1.4V. The fact that this voltage is positive and that the phase-shift from this input to the output is zero degrees means that the output is stable until something happens to upset the situation.

This 'something' occurs when the rising voltage at the inverting input reaches 1.4V also. At this point the two inputs are equal and, in theory anyway, the output falls to zero volts. What happens in practice is that, as the capacitor voltage just exceeds +1.4V (even by a fraction of a millivolt), the output switches from positive to negative saturation. This is because the voltage at the inverting input is now 'more positive' than that at the non-inverting input and, since there is a 180 degree phase-shift between this input and the output, the voltage at the latter reverses in polarity. This reversal of output polarity means that the voltage fed back to the non-inverting input will now be −1.4V. The capacitor voltage, which was previously an increas-

ing positive one, will now reverse in direction, 'aiming towards' the negative supply voltage. It is not too difficult to predict what will happen when it reaches −1.4V! The circuit will switch over again. These cycles repeat indefinitely, causing a continuous square-wave to be generated.

The frequency of the square-wave can be calculated from the fact that the time between switching instants (the time of half a cycle), known as t_s, is equal to $R1.C1.\ln[1 + (2R3/R2)]$. The frequency is equal to $1/2t_s$. $R1.C1$ is the product of the timing components; ln stands for the natural logarithm (base e).

For example, if R1 = R2 = 100k, R3 = 22k and C1 = 100nF, the calculated result gives a frequency of 137Hz. Try it and check this calculation. Then, using either these values or your own, compare the calculated and measured values obtained by hooking up the circuit and proving that it really does work. Using a CRO, look at the waveforms at both inputs and at the output. It is useful to use the d.c. input facility on the CRO and to sketch the waveforms to actual voltage and time scales. The waveforms at the two inputs should be compared with each other and with the value of fed-back voltage calculated from the values of R2, R3 and the magnitude of the output voltage.

Figure 2 shows this circuit adapted to produce a 1Hz TTL compatible square-wave. The frequency is determined by the circuit constants as before. The output amplitude can be set to the required value
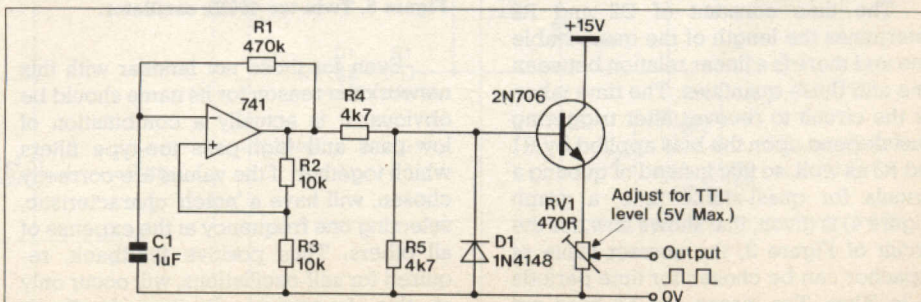

Figure 2. TTL 1Hz pulse generator.

by adjustment of RV1. The diode D1 prevents large negative excursions at the base of the emitter follower.

As a Monostable Multivibrator

A monostable circuit, as the name implies, has one stable state only; this is the one in which it normally rests. It has to be triggered to go into the other state, known as the 'quasi-stable' state. It remains in this latter state for a period of time determined by the time constant provided by a RC combination. A circuit to perform this function is shown in Figure 3.
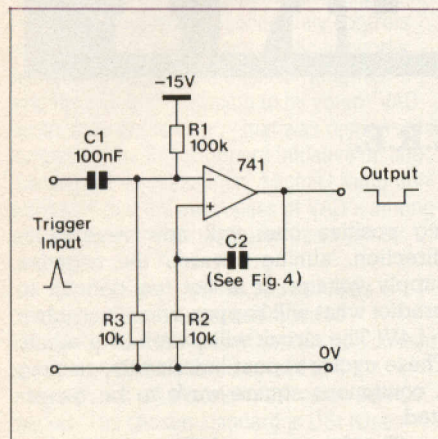

Figure 3. Monostable multivibrator.

For a monostable to remain in its stable state, some bias must be provided. In the figure this bias is obtained by taking the inverting input to a negative potential whose value is determined by the potential divider R1 and R3. For the values shown this voltage is about −1.4V. This means that the output of the Op-amp is normally held in positive saturation (because of the 180 degrees phase-shift). To trigger it, either a positive pulse or a square-wave (which will be differentiated by R3 and C1) has to be applied. When it is, the output switches to negative saturation, immediately coupling back a large negative voltage to the non-inverting input, via C2, the effect of which is to hold the circuit in the new state. However, since this large negative voltage also exists across R2, a current will now flow in the latter so that C2 will charge up, its left-hand plate rising exponentially towards 0V. When it reaches the same value of negative voltage as exists at the inverting input (−1.4V), the output switches back to positive saturation; in other words the circuit returns to the stable state.

The time constant of C2 and R2 determines the length of the quasi-stable time and there is a linear relation between time and these quantities. The time taken for the circuit to recover after triggering must depend upon the bias applied by R1 and R3 as well, so that instead of quoting a formula for quasi-stable time, a graph (Figure 4) is given, that shows how, for the circuit of Figure 3, the correct value of capacitor can be chosen for time periods up to 50ms. The circuit can be tried out with a number of different values of C2 to

verify the truth of this graph. Also other values of R2 can be tried, e.g. 100k, 470k, to obtain longer time intervals.
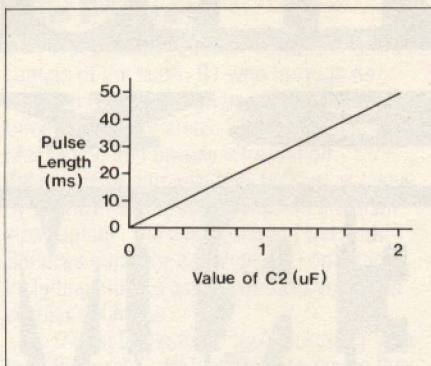

Figure 4. Graphical relation between C2 (in Figure 3) and output pulse duration of monostable circuit.

What is the effect of re-triggering the circuit before it has recovered? If the explanation has been properly understood, the answer should be obvious. Practice will, of course, prove the truth, one way or the other.

As a Generator of Sinewaves

An amplifier together with a suitable feedback circuit can be used to generate sinewaves. Of those possible, the twin-tee and Wien networks are of particular interest. Figure 5 shows an Op-amp combined with a twin-tee network to generate audio-frequency sinewaves.
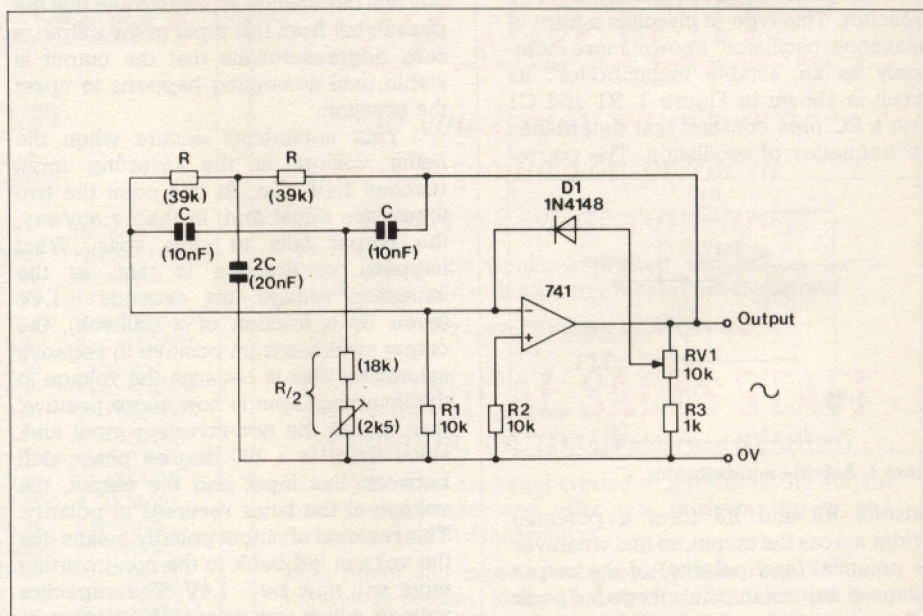

Figure 5. Twin-tee 400Hz oscillator.

Even for those not familiar with this network the reason for its name should be obvious. It is actually a combination of low-pass and high-pass tee-type filters which together, if the values are correctly chosen, will have a 'notch' characteristic, selecting one frequency at the expense of all others. Thus positive feedback, required for self-oscillations, will occur only at this frequency. Positive feedback implies a total of 360 degrees phase-shift

around the loop and this circuit meets that requirement. The Op-amp (using the inverting input) provides 180 degrees, the twin-tee network, at the selected frequency, provides the other 180 degrees. There is a loss in the network, of course, as there always is in any oscillator but this is compensated for by the amplifier gain. The frequency at which this happens is given by:

$$f = 1/(2 \pi RC)$$

To ensure that the generated sine-wave does not contain too much distortion some means must be employed to prevent the circuit from oscillating too hard. In this circuit two methods are used. The preset 2k5 resistor (part of R/2) 'detunes' the filter slightly and should be adjusted for the best waveform. Also a portion of the output, picked off by RV1 and R3 and applied to the inverting input by diode D1, is used to help stabilise the output amplitude. RV1 should also be adjusted for optimum quality of output. The output obtainable with the circuit shown is about 8.5V peak-to-peak.

This type of oscillator is useful where there is a need for just one, or perhaps a few spot frequencies. Varying the frequency continuously is awkward because it means varying three quantities simultaneously, e.g. the resistors R and R/2. The values given for the filter components in Figure 5 give an operating frequency of approximately 400Hz. An alternative oscillator that can be made continuously variable with greater ease is the Wien bridge type.

The Wien network, shown in Figure 6, consists of a series RC combination together with a parallel RC combination, the values of R and C usually being the same for both, though they don't have to be. This network has the characteristic that, at a particular frequency, the phase-shift is zero degrees with a loss of 3:1. The input would be applied across the
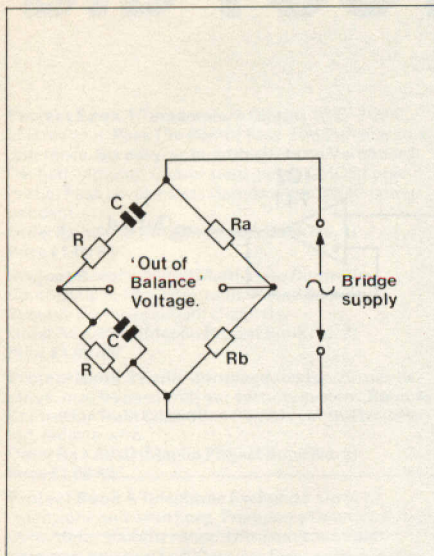
Figure 6. The Wien bridge network.

whole network and the output taken across the parallel RC combination. It would seem that the obvious way to use it would be as a feedback network between the input and output of an amplifier whose gain was 3 times and whose phase-shift was zero degrees. However, it is rarely used in this way because a practical oscillator must not only generate oscillations but must have automatic control of their amplitude, especially as the oscillator frequency is changed. Otherwise the output may increase to a level where unacceptable distortion occurs or the oscillations may cease altogether.

This automatic control of amplitude is achieved by using the Wien RC combinations as the two arms of a bridge, the other two arms being formed as follows. One arm is a fixed resistor but the other arm is a non-linear resistive device, normally a thermistor. The bridge is arranged so that, when the circuit is oscillating properly, there is a small out-of-balance voltage across the opposite junctions of the bridge (Figure 6). This provides the input to a high-gain amplifier, the Op-amp. The bridge 'supply' is the oscillator output voltage. Thus, any change in the latter causes a change in the current through the non-linear device. As a result its resistance changes and the bridge 'out-of-

balance' voltage either increases or decreases, resulting in a greater or lesser input to the amplifier, and a change in the amplifier output in such a direction as to restore it to the correct value.

There are various ways of providing the non-linear element. If the expense can be justified then the use of an R53 N.T.C. thermistor gives the most effective solution, but this type of thermistor is very expensive. If used it substitutes for Ra in Figure 6. An alternative is to use a low current lamp (less than 50mA current rating together with a suitable voltage rating) in place of Rb in Figure 6. This is obviously quite a cheap solution. Another possibility is the one shown in the full Wien bridge oscillator circuit of Figure 7.

In this circuit the non-linear device consists of two diodes, connected back-to-back, again an inexpensive answer. A preset resistor is connected in parallel with these diodes so that the bridge can be balanced so as to give a good waveform at the output. Otherwise, there is nothing remarkable about the circuit. Frequency control is achieved by means of the twin-gang potentiometer, each section of which has a certain amount of fixed resistance in series with it. This is essential to avoid the oscillator 'dying' when it tries to produce infinite frequency as the potentiometer resistance approaches zero, at one end of the wiper travel! As stated previously, the bridge is supplied from the oscillator output and the 'out-of-balance' voltage from the bridge is applied between the two inputs of the amplifier. An output control, RV4, is also provided. With the values shown in the figure the frequency range obtained should be from about 220Hz to 1kHz. With the same R and C values in both halves of the Wien network, the frequency is equal to $1/(2 \pi RC)$.

As an Active Filter

The function of any filter is to separate out a frequency, or band of frequencies, from a much wider frequency spectrum. For example, a low-pass filter will pass all frequencies below a particular 'cut-off' frequency; a high-pass filter will do the same for frequencies above cut-off and 'band-pass' and 'band-

stop' filters pass or reject whole bands of frequencies. It is also possible to select or reject a single frequency. Various combinations of L, C and R can be used to make filters and, if these 'passive' quantities are combined with amplification, the result is an 'active filter'.

A filter of this type is shown in Figure 8. It makes use of the properties of the twin-tee network, not to generate a sinewave of a particular frequency as was seen in Figure 5, but to give selective amplification to one frequency. To do this the network is connected as a feedback path between the output and the inverting input. What we then have is an inverting amplifier whose gain is determined by the impedance of the twin-tee network divided by the input resistance. Since the impedance of the twin-tee network is a maximum at a frequency equal to $1/(2 \pi RC)$, then the gain of the circuit will be a maximum at this frequency. The selectivity of this circuit can be improved in two ways, by using the preset shown in the R/2 branch to 'tweak' the response and by including a 'bass-cut' capacitor, C1, equal in value to 2C in the twin-tee network. The 'centre frequency' for the values given is about 400Hz. It is well worth while experimenting with this circuit, plotting the amplifier output against frequency and trying the effect of tweaking the response as just mentioned. Naturally an electronic voltmeter or a CRO will be needed to measure the output voltage.

As a Peak Signal Detector

While voltmeters for measuring a.c. are invariably 'mean-sensing, r.m.s. calibrated', there is sometimes a need for one that will register peak or even peak-to-peak values, regardless of the waveform.

The circuit is shown in Figure 9 and employs two Op-amps, IC1 which is the peak detector itself and IC2, a voltage follower to buffer the output for any connected load. Diode D1 determines which peak of the waveform is being measured and, with the polarity shown, will measure positive peaks. Reversing it allows it to measure negative peaks instead. The circuit works as follows.
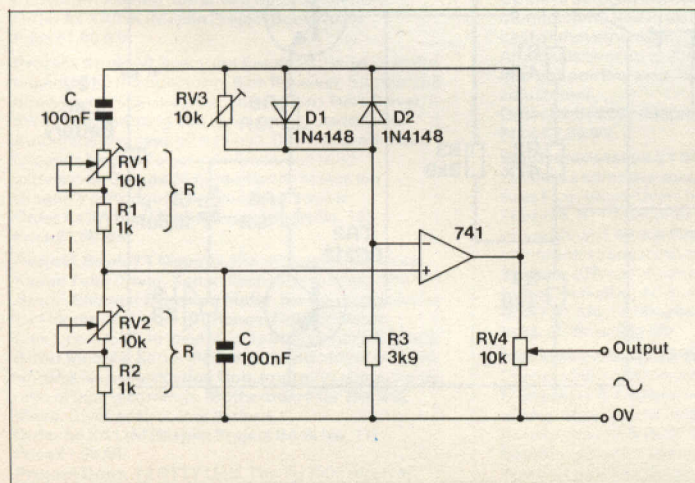

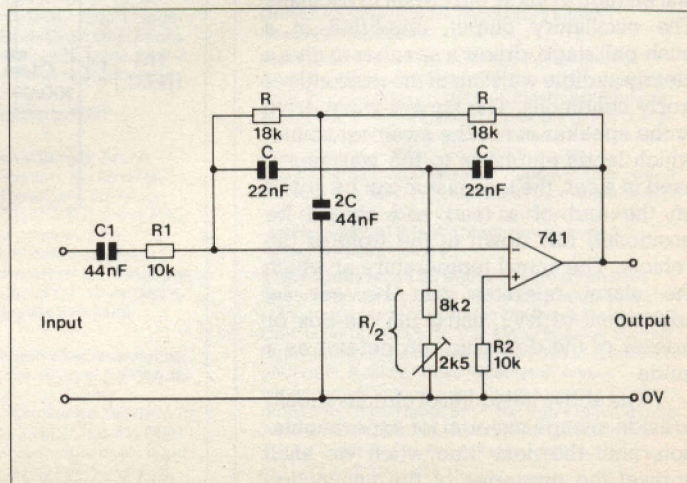**Figure 7. Wien bridge oscillator 220Hz – 1kHz.**

Figure 8. 400Hz twin-tee selective amplifier.

If switch S1 is closed capacitor C1 can be assumed to be discharged. The only way that C1 can now acquire a charge is through the diode D1, switch S1 then being open. A positive going voltage at the non-inverting input, even an extremely small one, will cause the diode to conduct, because of the very high gain of the Op-amp. The capacitor will charge up to the highest voltage applied to it and will allow this value to be read. Over a period of time there will be a leakage of charge since the input impedances of the Op-amps, while being very high, are not infinite. The circuit can be reset at any instant by closing S1.

In Figure 10 the same principle is extended to measure peak-to-peak values of any waveform; it doesn't matter whether the two peaks are equal or not. Two peak detectors, of the type of Figure 9, are used. One measures positive peaks, the other negative ones; note the polarity of the two diodes, D1 and D2. The two outputs will be in antiphase to each other. To obtain their 'sum', it is only necessary to feed them into a 'subtractor' circuit! If the two peak voltages are V1 and −V2 respectively, the subtractor will produce the result, V1 − (−V2) = V1 + V2, the peak-to-peak value of the input. IC3 is the subtractor circuit.

A Practical Application for an Op-amp

Finally, a really practical application for an Op-amp a 'frost alarm' for a car (or even a greenhouse?). The circuit for this is shown in Figure 11.

It is back to the Op-amp astable multivibrator with this circuit. RV1 and C1 form the timing components that determine the frequency. R1 and R2 set the potential at the non-inverting input. However, an extra component has been added, a N.T.C. (Negative Temperature Coefficient) thermistor, Th1. This has a resistance that 'increases' as the temperature 'decreases'. Since it is wired in parallel with C1, the latter tends to discharge through it. The lower the resistance of Th1 the more of C1's charge it 'steals'. But if the temperature is low enough, the resistance of Th1 will become quite high and C1 will be able to charge fast enough to allow the circuit to oscillate. The oscillatory output, amplified in a push-pull stage, drives a speaker to give a clearly audible warning of the presence of frosty conditions. The square-wave drive to the speaker is not the sweetest sound, which lends emphasis to the warning! If used in a car, the thermistor can be wired on the end of a lead and should be positioned low down at the front of the vehicle. The actual temperature at which the alarm operates can be set by adjustment of RV1, using the ice-box or freezer of the domestic refrigerator as a guide.

The above selection of circuits should provide enough material for experimentation, until the next time when we shall unravel the mysteries of the unijunction transistor.
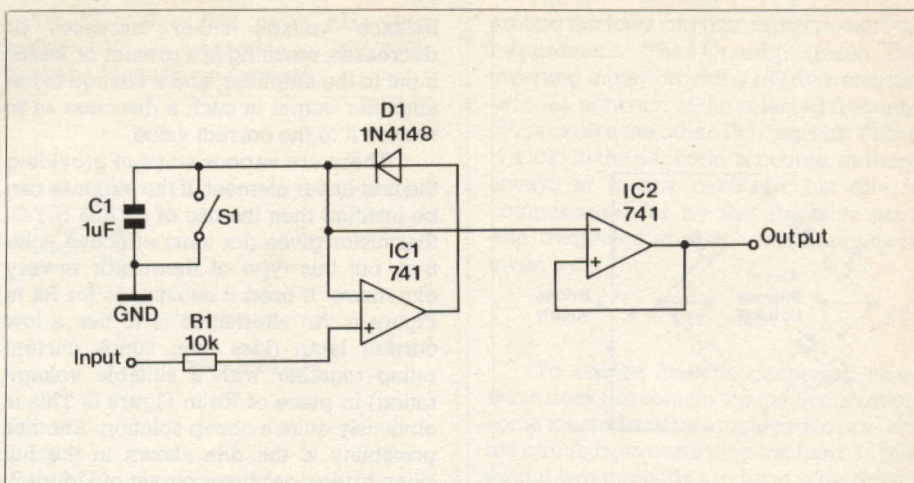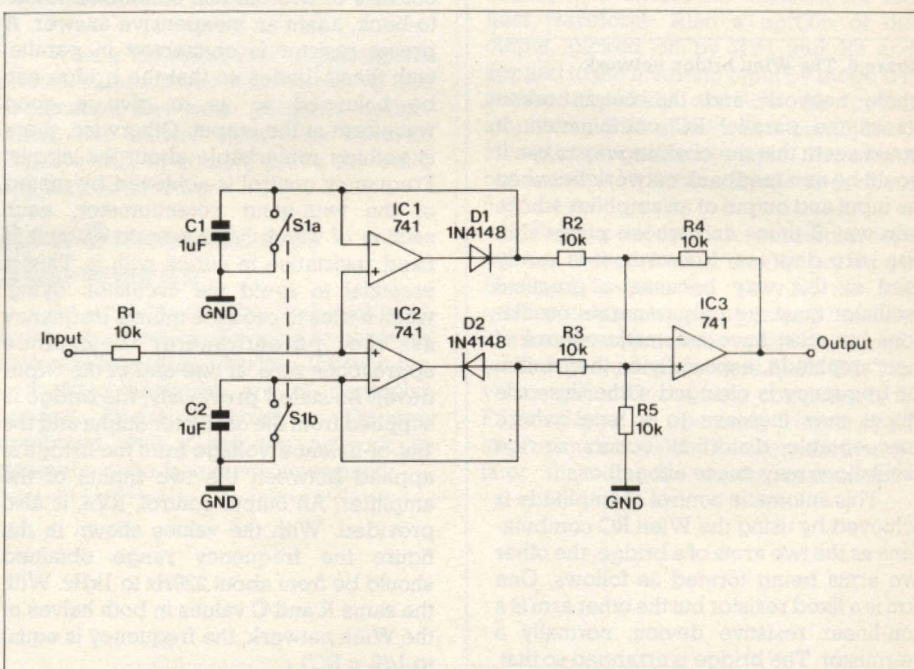

Figure 9. Peak voltage detector.
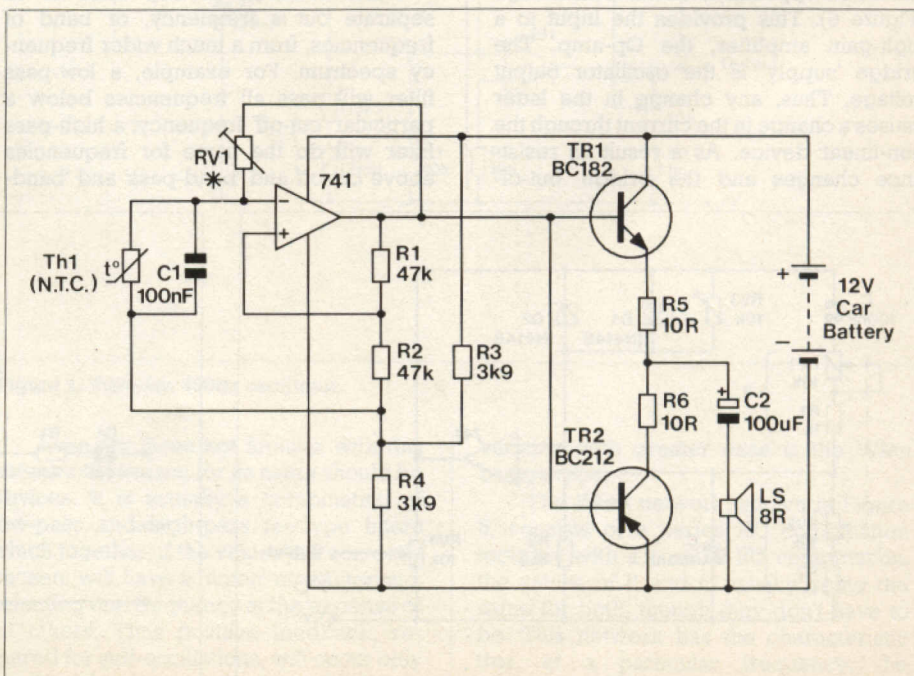

Figure 10. Peak-to-peak voltage detector.

Figure 11. Frost alarm for car. *Chosen to suit Th1, adjusted to equal Th1 at 'Alarm' temperature.

DIGITAL PANEL METER

Reviewed by
Gavin Cheeseman

Introduction

The SM-43 Digital Panel Meter is one of the new range of kits from Sound Master Electronics, marketed by Maplin. In its most basic form the SM-43 will provide a digital readout of voltage up to 200mV, with provision for extra on board components, allowing operation on any one of eight different current and voltage ranges.

My first impression of the kit was that of a high quality product which is very well presented. I thought that the quality of the PCB was very good and I found the large, 15mm high red seven segment LED display quite impressive! A plastic case is provided in the kit to house the display and electronics and I think this really adds a professional touch to the finished product. The kit comes complete with a comprehensive instruction manual giving full information on how to build and test the panel meter. The circuit (Figure 1) and PCB layout (Figure 2) diagrams are included in this review for reference purposes.

Construction

In addition to the parts supplied, a soldering iron, some solder and a few simple tools are required to build the kit. A multimeter is also needed when aligning the finished module. Before attempting any construction I think it is always a good idea to spread the components out on a table and check them against the parts list to make sure that they are correct; if all is well, then construction may commence. I recommend that the parts are fitted in the order suggested in the instruction manual as this takes the sizes of the various components into consideration and is usually the easiest method. The SM-43 can be constructed for operation on any one of nine different voltage and current ranges with full scale deflections ranging from 199.9mV to 199.9V and 199.9μA to 1.999A. The kit contains all the components necessary for operation on the 199.9mV range; however, if operation on one of the other ranges is required this may be arranged by fitting resistors of the appropriate value (not supplied) as explained in the instruction manual and shown in Table 1. It is nice to see that IC sockets are included in the kit; the use of these helps to prevent any damage that could occur due to soldering the IC's directly into the PCB and also makes IC removal much easier should this be necessary at any time. Whilst fitting the capacitors, I noticed that 200nF (instead of 220nF) capacitors had been supplied;

Range (FSD)	R1	R2	R3	R4	R5
199·9mV	N.F.	L	N.F.	390R	10k
1·999V	N.F.	10M	1M	2k	L
19·99V	N.F.	10M	100k	390R	10k
199·9V	N.F.	10M	10k	390R	10k
199·9uA	1k	L	N.F.	390R	10k
1·999mA	100R	L	N.F.	390R	10k
19·99mA	10R	L	N.F.	390R	10k
199·9mA	1R	L	N.F.	390R	10k
1·999A	0·1R (3W)	L	N.F.	390R	10k

Table 1. Various resistor values required for different ranges. NF equals Not Fitted and L equals Linked.
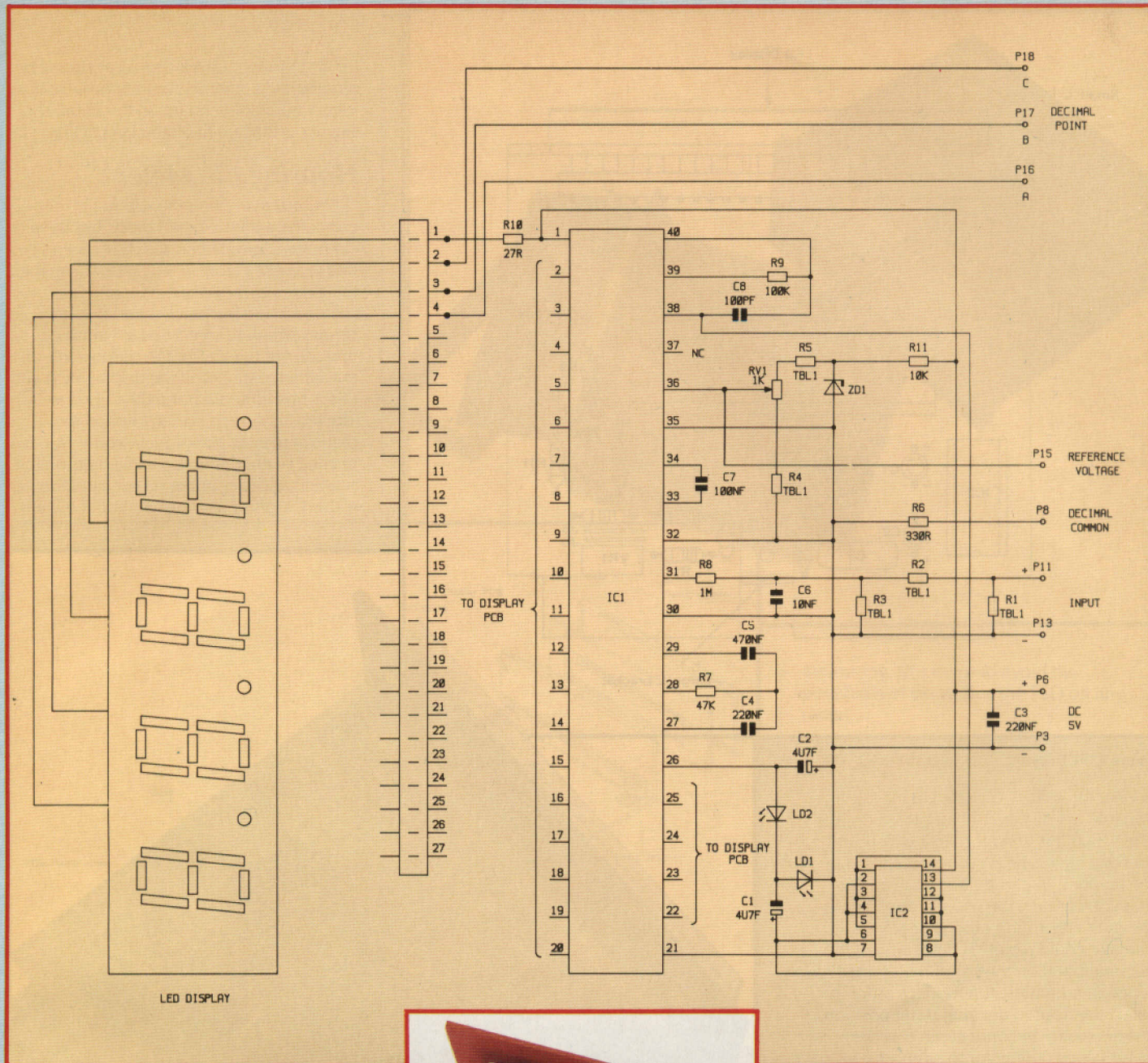
Figure 1. Circuit.

this doesn't make any difference. Care is needed when fitting the carbon preset as it is relatively fragile and easily damaged if stressed in any way. As supplied, the LED display is mounted on its own separate PCB; this is connected to the main PCB by a link comb which consists of a number of wire links separated by a plastic spacer. I think the use of a link comb is a good idea because it is somewhat easier to fit than individual links and also if fitted properly adds to the neatness of construction. When cutting the link comb, as shown in the instruction manual, please make sure that you leave the correct number of links on the comb! In addition to the links made using the link comb, there are six other links to be fitted. Insulated wire has been supplied in the kit, instead of the BTC type mentioned in the instruction manual. When fitting these links, cut the wire to the appropriate length and strip a few millimetres of insulation from the ends of the wire; the links may then be fitted in the usual way. Brackets, nuts and bolts are supplied in the kit to fix the display PCB to the main PCB. I suggest that you do not install the finished module into its case
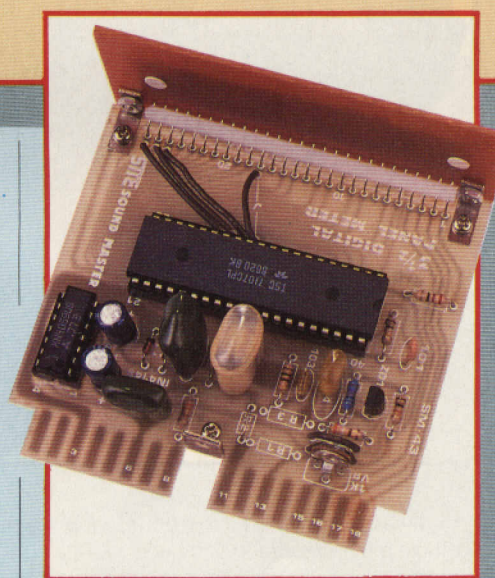
until it has been basically tested and aligned.

Power Supply

A 5V DC regulated power supply which is capable of delivering at least 100mA is required to power the panel meter. If you are using a mains operated power supply, it is important to make sure that its output is adequately decoupled, as

the introduction of mains derived noise onto the supply rail could produce erroneous results. The panel meter can of course be powered from a battery supply, but its relatively large current drain must be taken into consideration when choosing batteries!

Testing and Calibration

Before applying any power to the panel meter, it is a good idea to inspect your work to make sure that the components are fitted correctly and to check that there are no problems with the soldering; in particular make sure that the semiconductors and electrolytic capacitors are the right way round. It is a good idea to measure the resistance between the power supply pins (pins 3 and 6) using a multimeter, to make sure that they are not short circuit.

I used an edge connector (Maplin stock code JB64U) to make the external connections, as this makes the installation and removal of the panel meter somewhat easier than if the wires were soldered directly to the PCB. Please note: The edge
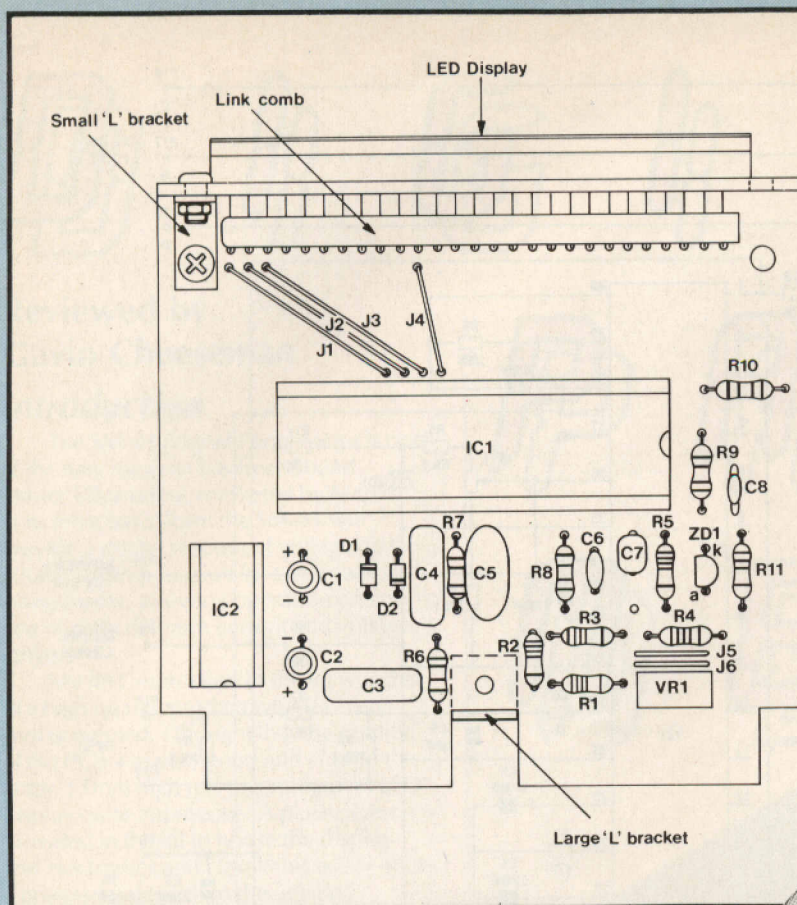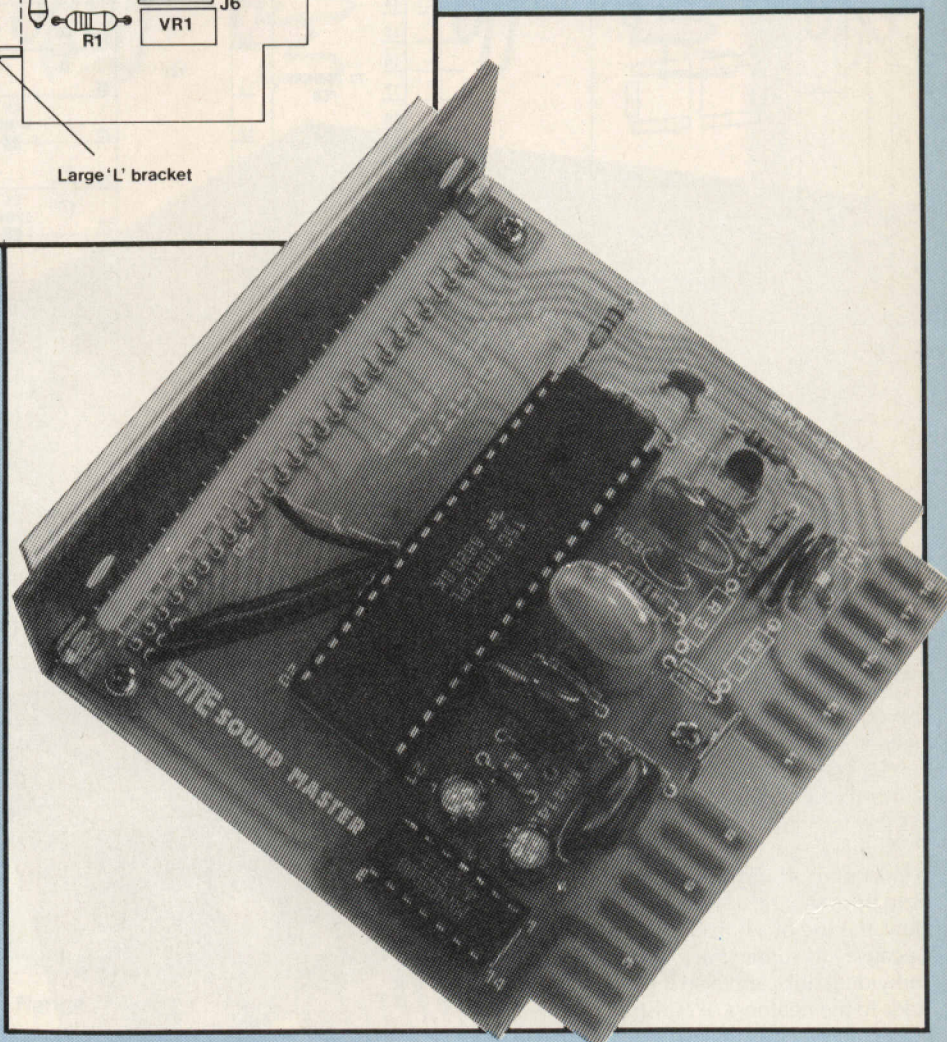
Figure 2. PCB layout.

to 90mA maximum. It should of course be remembered that the current consumption is very much dependant on the number of segments that are lit on the LED display.

Housing the Meter

Once everything is working correctly, after the panel meter has been calibrated, it can be installed in its housing, see Figure 3. The PCB slides into the guides in the plastic case and is secured using the bracket and fixing screws supplied. A cardboard mask is included in the kit, for the purpose of masking the tracks on the display PCB and this is positioned around the LED display. The plastic screen is then clipped into place in front of the display; some care is needed while doing this as the lugs on the screen are easily broken if excessive force is used. I found the finished panel meter

connector is NOT supplied in the kit. If you use an edge connector please double check that it is fitted the right way round and that all wiring is correct as shown in the manual; in particular please ensure that you connect the power supply leads the right way round otherwise severe damage could result! The position of the decimal point on the panel meter display is not an automatic function. In order to select the desired decimal point position, it is necessary to connect pin 8 of the SM-43 edge connector to either pin 16, 17 or 18 as explained in the instruction manual; this should be arranged so that the decimal point is placed correctly for the range that has been chosen. When power is applied to the panel meter, the display may show some random numbers if the input terminals are left open circuit; however, if the input terminals are shorted together 000 should then be displayed. In order to calibrate the SM-43, a multimeter and a suitable voltage or current source are required; methods of producing suitable sources are shown in the instruction manual. I found that the formulae shown in the manual only give a rough approximation of the level of voltage or current produced by the source, so the panel meter should be calibrated against a multimeter for accurate results. The SM-43 is calibrated by adjusting VR1 until the panel meter readings agree with those of the multimeter. In addition to displaying the magnitude of measured voltage or current, the SM-43 will also indicate its polarity. If the input pins of the panel meter are connected to the calibration source with reverse polarity, a negative symbol should show to the left of the display indicating this fact.

I was pleased to see that a precision voltage reference diode had been incorporated in the design of the panel meter as this keeps the basic level of accuracy and stability relatively high. Although the basic accuracy of the panel meter is very good, it should be borne in mind that the accuracy of the reading is still very much dependant on the precision of the multimeter with which the SM-43 has been calibrated and to a lesser extent the ambient temperature.

I measured the current consumption of the SM-43 and found it to be around 85

looked quite impressive once it was housed in its case. One useful feature of the SM-43 is that the alignment preset (VR1) can be accessed through a hole in the back of the case; this facilitates any final adjustments once installation is complete and makes any periodic alignment much simpler. You will need to exercise care when adjusting VR1 because it is quite fragile and easily damaged if too much force is used!

It is worth pointing out that in order to fit the edge connector, when the meter is installed in its case, it is necessary to

remove the edges of the bottom two plastic pillars on the rear of the housing.

Applications

I think the SM-43 could be of use in many different applications where a display of voltage or current is required and it is also possible to use the meter in conjunction with other external circuitry, to display quantities such as resistance or frequency. It would be interesting to experiment with an external resistor network to enable a series of voltage or current ranges to be selected; remember that the position of the decimal point must also be switched to suit the selected range. When using current shunts to provide different ranges, remember to make sure that the power handling capability of the shunt resistor is sufficient
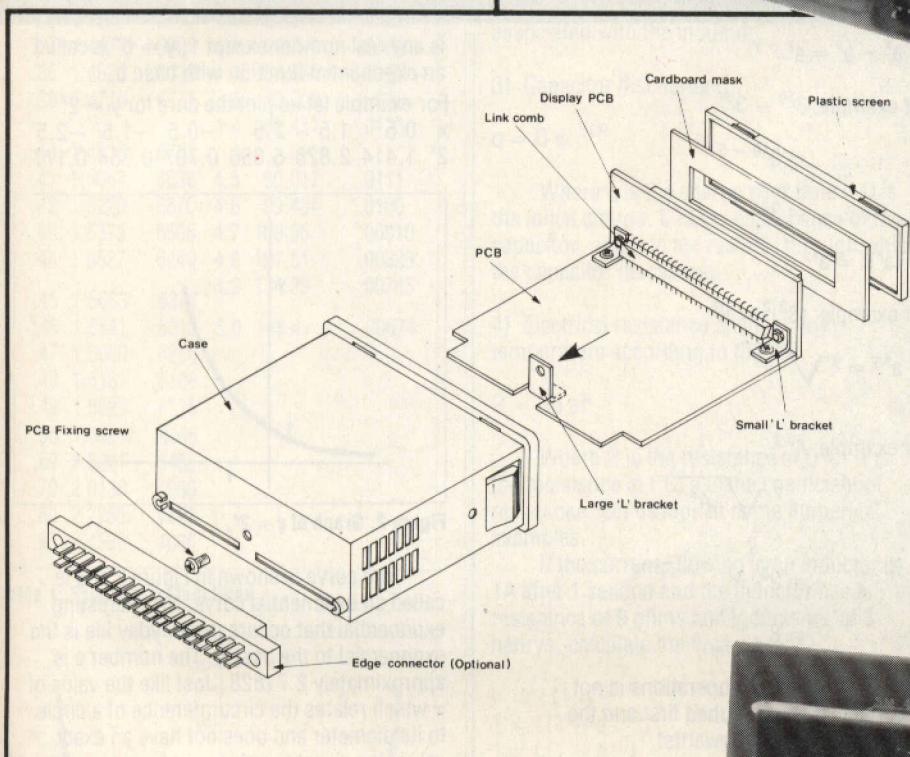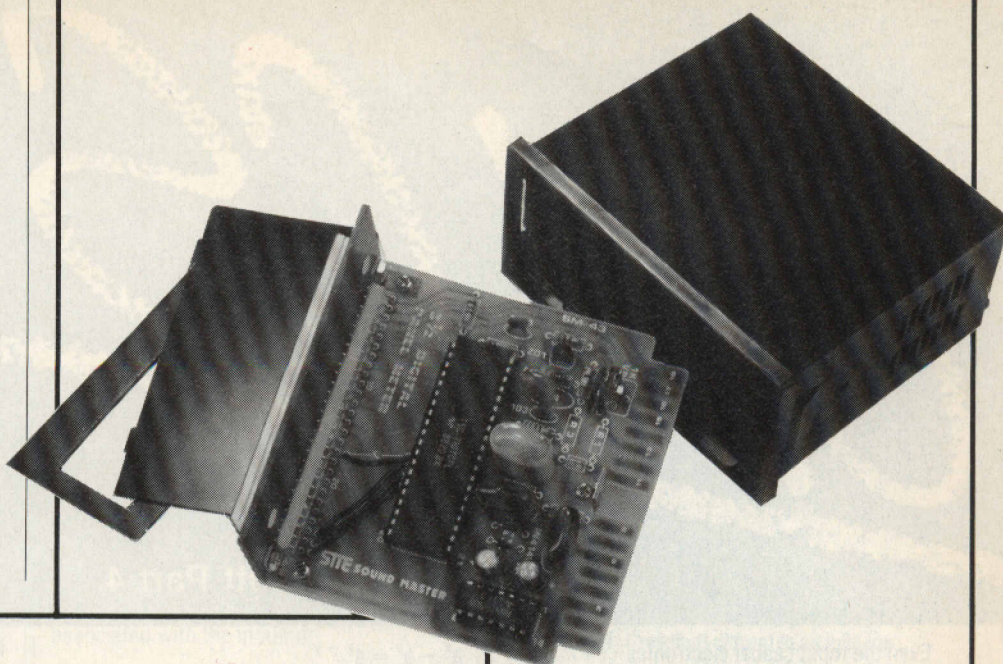

Figure 3. Case assembly.

to dissipate any heat produced, otherwise overheating could take place.

I also found that a useful feature of the SM-43 is its very high input resistance when operating on voltage ranges (around 100MΩ); this means that the meter produces negligible loading on the circuit being tested, making it generally unnecessary to take the resistance of the meter into consideration when making voltage measurements. When used on a current range, the resistance of the meter is basically dependant on the value of the shunt resistor (R1). It is worth keeping in mind the fact that this meter should not be used in situations where the input voltage or current is likely to exceed full scale deflection (FSD), for the range in use, as damage could occur. If you are using an external resistor network to provide a selection of switchable ranges, I suggest that you start the measurement on the highest range and switch to lower ranges, as appropriate, when you have an idea of the magnitude of the quantity that you are

measuring; this helps to avoid the possibility of exceeding the FSD on any range.

Conclusion

I was quite impressed with the presentation of the SM-43. In particular, a lot of thought has been put into the look of the final product. The quality of the parts was generally good and the finished meter performed well when tested. I found the SM-43 a pleasure to use and hope you have a similar experience if you decide to build the kit. As always I would like to thank Maplin Electronics for providing the review sample.
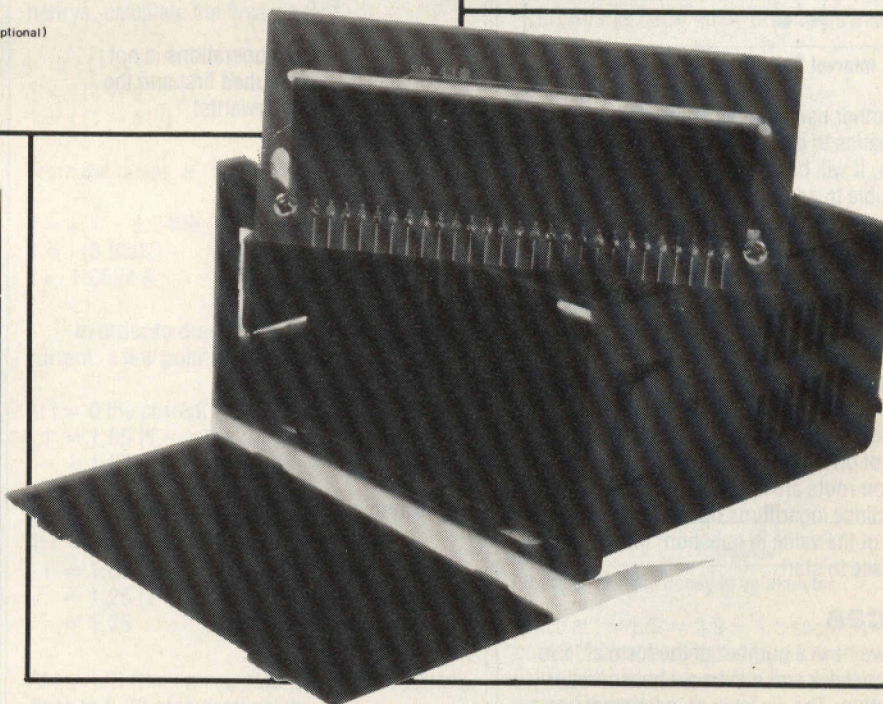
The SM-43 Digital Panel Meter Kit from Sound Master is available from Maplin Electronics:

Order As LM70M (DPM Kit) Price £24.95

CALCS

by Jeff Scott Part 4

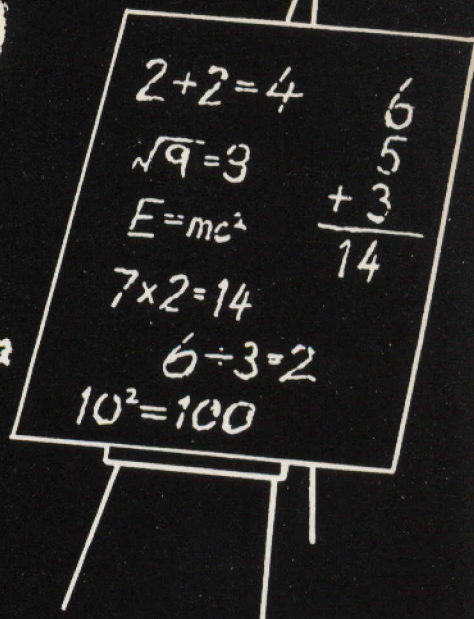Even the most casual electronics hobbyist must, at some time, feel like designing his own circuit or at least modifying some aspect of circuit performance. For instance, tired of watching a multivibrator flick lights on and off at a fixed pace, one may wonder how to alter the timing. Immediately one is faced with the equation:

$$T = t \log e \left(\frac{V_2}{(V_1 + V_2)} \right)$$

Where V_1 and V_2 are the multivibrator voltage, t is the product of resistor and capacitor, T is the interval of half the waveform shown in Figure 1. We shall see later how to solve equations with logarithms to the base e.
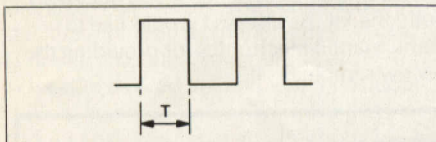

Figure 1. Interval T of a digital waveform.

Another useful application of mathematics to electronics is in the use of decibels. It will become clear why it is permissible to add or subtract decibel values in the section on logarithms.

Introducing the tables invented by Napier, Mr Briggs wrote in 1631, "logarithams are numbers invented for the more easier working of questions in arithmetic and geometry . . . by them all troublesome multiplication and divisions are avoided and performed only by addition instead of multiplication and by subtraction instead of division. The curious and laborious extraction roots are also performed with great ease". Since logarithms operate on the powers of the value in question, indices are a good place to start.

Indices

If we have a number of the form a^x, x is called the index and can be a whole number or a fraction. The six laws of indices are:

1. $a^x \times a^y = a^{x+y}$

For example: $2^7 \times 2^8$
$$= 2^{15}$$

2. $a^x - a^y = a^{x-y}$

For example: $3^{10} - 3^5$
$$= 3^{10-5}$$
$$= 3^5$$

3. $(a^x)^y = a^{xy}$

For example: $(8^3)^2 = 8^6$

4. $a^{x/y} = \sqrt[y]{a^x}$

For example: $4^{3/2}$
$$= \sqrt[2]{4^3}$$
$$= 2^3$$
$$= 8$$

The order of the operations is not important. It can be cubed first and the square root taken afterwards!

$$4^{3/2}$$
$$= (64)^{1/2}$$
$$= 8$$

5. $a^0 = 1$

For example: $5^0 = 1$

6. $a^{-x} = \frac{1}{a^x}$

For example: 4^{-3}
$$= \frac{1}{4^3}$$
$$= \frac{1}{64}$$

Exponents

Power functions like x^3, x^4 are of the form x^b where the power is a constant. If we interchange this to b^x where the power is variable, we have an exponential function. If b is any real number except 1, $y = b^x$ is called an exponential function with base b.

For example let us plot the cure for $y = 2^x$:

x	0.5	1.5	2.5	−0.5	−1.5	−2.5
2^x	1.414	2.828	5.656	0.707	0.354	0.177
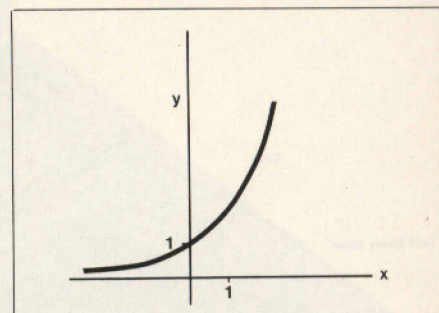
Figure 2. Graph of $y = 2^x$.

The curve is shown in Figure 2 and is called an exponential curve. An interesting exponential that occurs in everyday life is the exponential to the base e. The number e is approximately 2.71828. Just like the value of π which relates the circumference of a circle to its diameter and does not have an exact value, the quantity e does not have an exact value.

Tables exist for values of e^x where x can be a positive or negative number, a small sample is shown in Table 1. Alternately a scientific calculator with an e^x key can be used to calculate individual values.

x	e^x	e^{-x}	x	e^x	e^{-x}
.02	1.0202	.9802	1.0	2.7183	.3679
.04	1.0408	.9608	1.1	3.0042	.3329
.06	1.0618	.9418	1.2	3.3201	.3012
.08	1.0833	.9231	1.3	3.6693	.2725
			1.4	4.0552	.2466
.10	1.1052	.9048			
.11	1.1163	.8958	1.5	4.4817	.2231
.12	1.1275	.8869	1.6	4.9530	.2019
.13	1.1388	.8781	1.7	5.4739	.1827
.14	1.1503	.8694	1.8	6.0497	.1653
			1.9	6.6859	.1496
.15	1.1618	.8607			
.16	1.1735	.8521	2.0	7.3891	.1353
.17	1.1853	.8437	2.1	8.1662	.1225
.18	1.1972	.8353	2.2	9.0250	.1108
.19	1.2092	.8270	2.3	9.9742	.1003
			2.4	11.023	.0907

| x	e^x	e^{-x}	x	e^x	e^{-x}
.20	1.2214	.8187			
.21	1.2337	.8106	2.5	12.182	.0821
.22	1.2461	.8025	2.6	13.464	.0743
.23	1.2586	.7945	2.7	14.880	.0672
.24	1.2712	.7866	2.8	16.445	.0608
			2.9	18.174	.0550
.25	1.2840	.7788			
.26	1.2696	.7711	3.0	20.085	.0498
.27	1.3100	.7634	3.1	22.198	.0450
.28	1.3231	.7558	3.2	24.532	.0408
.29	1.3364	.7483	3.3	27.113	.0369
			3.4	29.964	.0334
.30	1.3499	.7408			
.31	1.3634	.7335	3.5	33.115	.0302
.32	1.3771	.7261	3.6	36.598	.0273
.33	1.3910	.7189	3.7	40.447	.0247
.34	1.4050	.7118	3.8	44.701	.0224
			3.9	49.402	.0202
.35	1.4191	.7047			
.36	1.4333	.6977	4.0	54.598	.0183
.37	1.4477	.6907	4.1	60.340	.0166
.38	1.4623	.6839	4.2	66.686	.0150
.39	1.4770	.6771	4.3	73.700	.0136
			4.4	81.451	.0123
.40	1.4918	.6703			
.41	1.5068	.6636	4.5	90.017	.0111
.42	1.5220	.6570	4.6	99.484	.0100
.43	1.5373	.6505	4.7	109.95	.00910
.44	1.5527	.6440	4.8	121.51	.00823
			4.9	134.29	.00745
.45	1.5683	.6376			
.46	1.5841	.6313	5.0	148.41	.00674
.47	1.6000	.6250			
.48	1.6161	.6188			
.49	1.6323	.6126			
.50	1.6487	.6065			
.60	1.8221	.5488			
.70	2.0138	.4966			
.80	2.2255	.4493			
.90	2.4596	.4066			

Table 1. Exponential functions.
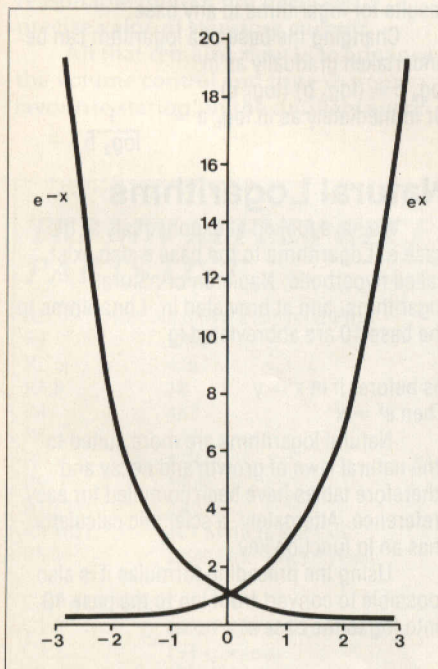
Figure 3. Graph of e^x and e^{-x}.

Using the tables, graphs of e^x and e^{-x} can be drawn as in Figure 3. For values of x as low as 3 the graph climbs rapidly towards infinity.

Examples of exponential growth or decay are:

1) Current increasing in an inductive circuit.

$$i = I(1 - e^{-Rt/L})$$

Where i is the instantaneous current at time t, I is the final current value, L is the inductance, and R is the resistance associated with the inductor.

2) Current decreasing in an inductive circuit.

$$i = I e^{-Rt/L}$$

Where i is the instantaneous current at time t, I is the initial current, L is the inductance, and R is the resistance associated with the inductor.

3) Capacitor discharging.

$$q = Q e^{-t/CR}$$

Where q is the charge after time t, Q is the initial charge, C is the capacitance of the capacitor, and R is the resistor through which the capacitor discharges.

4) Electrical resistance changes with temperature according to the law.

$$R = R_0 e^{at}$$

Where R is the resistance at 0°C, R_0 is the resistance at t°C, a is the coefficient of resistance. Let us look at some numerical examples.

If the current i flowing in an inductor is 1A after 1 second and the inductor has a resistance of 9 ohms and inductance of 3 henrys, calculate the final current?

$i = I(1 - e^{-Rt/L})$
$1 = I(1 - e^{-9/3})$
$1 = I(1 - e^{-3})$

From the tables: $e^{-3} = 0.0498$

$1 = I(1 - 0.0498)$
$1 = I(0.9502)$
$I = 1.0524$ A

In order to draw the graph of the rising current, a few points need to be calculated.

At t = 0 the current is 0 since,
$i = 1.05(1 - e^{-0})$
$= 1.05(1 - 1)$
$= 0$

At t = ∞ the current is 2A since,
$i = 1.05(1 - e^{-∞})$
$= 1.25(1 - 0)$
$= 1.25$

At t = L/R (the time constant) the current has risen to 0.63 of its final value.

$i = 1.05(1 - e^{-1})$
$= 1.05(1 - 0.3679)$
$= 1.05(0.6321)$
$= 0.6642A$

We now have the following values:

t	0	0.33	1.0	∞
i	0	0.66	1.0	1.05
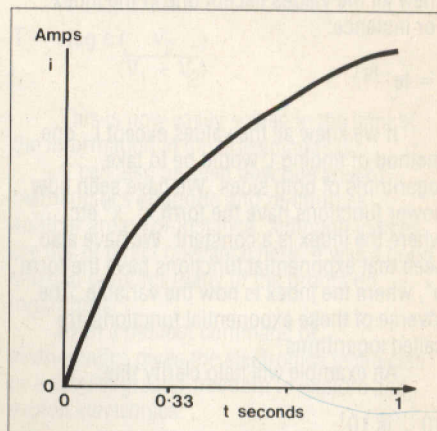
Figure 4. Growth of current in an inductor.

A graph is shown in Figure 4. Let's move on to another example.

Find the instantaneous current after 0.4 seconds when current is switched off in an inductor of 3 henrys and 9 ohms resistance. The initial current is 2A.

$i = I e^{-Rt/L}$
$= 2e^{-(9×0.4)/3}$
$= 2e^{-1.2}$ (from the tables $e^{-1.2}$ is 0.3012)
$= 2 × 0.3012$
$= 0.6024A$

In order to draw a graph of the decaying curve, more instantaneous values need to be calculated. We know that at t = 0, the current is a maximum of 2A, since $i = 2e^{-0} = 2 × 1 = 2$.
At t = ∞, $i = 2e^{-∞} = 0$

At t = L/R (called the time constant) the current has decayed by 0.63 of its initial value.

$i = 2e^{-1}$
$= 2 × 0.3679$
$= 0.7358$ A

Figure 5. Current decay in an inductor.

Since at t = L/R = 3/9 = 1/3 seconds the current has already fallen by 63% of its initial value, we need to calculate more values around this time.

t	0	0.2	0.33	0.4	∞
i	2	1.08	0.73	0.60	0

A graph is shown in Figure 5.

Logarithms

Suppose in the preceding equations we knew all the values except one in the index. For instance:
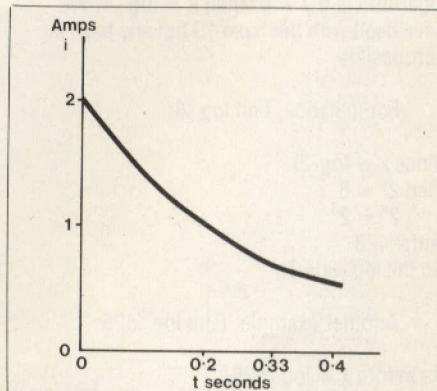
$$i = Ie^{-Rt/L}$$

If we knew all the values except L, one method of finding L would be to take logarithms of both sides. We have seen how power functions have the form x^2, x^3 etc. where the index is a constant. We have also seen that exponential functions have the form b^x, where the index is now the variable. The inverse of these exponential functions are called logarithms.

An example will help clarify this:

10 is 10^1
100 is 10^2
1000 is 10^3

So the logarithm of 10 to the base 10 is 1
the logarithm of 100 to the base 10 is 2
the logarithm of 1000 to the base 10 is 3

In this manner we are operating on the power alone. If we operate on the powers then by the rules of indices we add and subtract powers instead of multiplying or dividing.

For example:

$$10^2 \times 10^3 = 10^5$$

We can now see that since decibels are logarithmic ratios we are quite justified in adding and subtracting them instead of multiplying and dividing.

For instance, if an amplifier has a gain of 1,000,000 followed by an attenuator of 100:

log 1,000,000 = 6 Bels
log 100 = 2 Bels
Overall gain 6 − 2 = 4 Bels

The general definition then of a logarithm is if $y = b^x$ then $x = \log_b Y$. We have dealt with the base 10 but any base is permissible.

For instance, find $\log_2 8$:

Since $x = \log_2 8$
then $2^x = 8$
$2^x = 2^3$
and $x = 3$
So the $\log_2 8$ is 3.

Another example. Find $\log_5 625$:

As before $x = \log_5 625$
then $5^x = 625$
$5^x = 5^4$
$x = 4$

The logarithm of 625 to the base 5 is 4. Suppose the figure does not lend itself easily to whole powers as above, then ready tables to the base 10 or a calculator may be used.
For instance, solve for x in $2^x = 5$.
Taking logarithms of both sides to the base 10, $\log_{10} 2^x = \log_{10} 5$

(Now $\log_{10} 2^x$ may be written as $x \log_{10} 2$ as we shall see later).
$x \log_{10} 2 = \log_{10} 5$

$$x = \frac{\log_{10} 5}{\log_{10} 2}$$

$$= \frac{0.699}{0.301}$$

$$= 2.322$$

Properties of Logarithms

Let us look at some common properties of logarithms:

1) $\log_b MN = \log_b M + \log_b N$
Let $\log_b M = x$
$\log_b N = y$

Then $MN = b^x b^y$

$MN = b^{x+y}$ from the law of indices.

In logarithmic form:

$\log_b MN = x+y$
Therefore, $\log_b MN = \log_b M + \log_b N$
Hence the justification in adding decibels to obtain power gains.

2) $\log_b \dfrac{M}{N} = \log_b M - \log_b N$

As before let $M = b^x$
$N = b^y$

Then $\dfrac{M}{N} = \dfrac{b^x}{b^y}$
$= b^{x-y}$ from the law of indices.

In logarithmic notation:
$\log_b \dfrac{M}{N} = x - y$

Therefore, $\log_b \dfrac{M}{N} = \log_b M - \log_b N$

Hence the justification in subtracting decibels when there is an electrical power loss.

3) $\log_b N^a = a \log_b N$
By definition, if $\log_b N = x$
then $N = b^x$

Raising each side by the power of a.

$N^a = b^{ax}$

In logarithmic form:

$\log_b N^a = ax$
Therefore, $\log_b N^a = a \log_b N$

4) $\log_b 1 = 0$
Let $\log_b 1 = x$
Then $b^x = 1$

From the law of indices, if $b^x = 1$

Then $x = 0$
Therefore, $\log_b 1 = 0$

5) $\log_b b = 1$
Let $\log_b b = x$

By definition, $b^x = b$
Then x must equal 1
Therefore, $\log_b b = 1$

In words, the logarithm of any number to the same base as the number, is one.

6) $\log_b 0 \rightarrow -\infty$
Let $\log_b 0 = x$
By definition, $b^x = 0$

If b is a positive real number then x has to tend towards negative infinity.

For instance, $2^{-2} = 0.25$
$2^{-20} = 9.54 \times 10^{-7}$
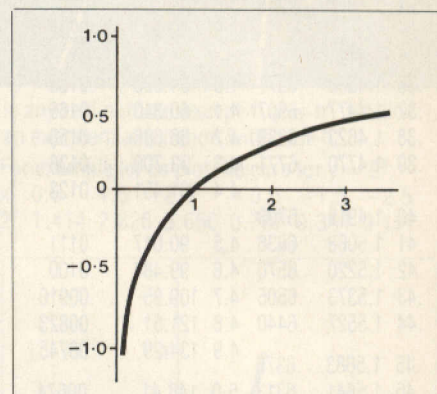
Figure 6. Graph of $y = \log_{10} x$ with $x \rightarrow$ zero.

Figure 6 shows a graph of $y = \log_{10}^x$ showing that as x tends to 0, y tends to minus infinity.

For instance, $\log_{10} 2 = 0.3$
$\log_{10} 0.2 = -0.7$

Although the graph is drawn for logarithms to the base 10, the same curve results for logarithms to any base.
Changing the base of a logarithm can be undertaken gradually as in:
$\log_a c = (\log_a b)(\log_b c)$
Or immediately as in $\log_b a = \dfrac{1}{\log_a b}$

Natural Logarithms

We have looked at exponentials to the base e. Logarithms to the base e also exist, called hyperbolic, Napieran or natural logarithms, and abbreviated ln. Logarithms to the base 10 are abbreviated lg.

As before, if $\ln x = y$
Then $e^y = x$

Natural logarithms are more suited to the natural laws of growth and decay and therefore tables have been compiled for easy reference. Alternately, a scientific calculator has an ln function key.

Using the preceding formulae it is also possible to convert from log to the base 10 into log to the base e.

$\log_a c = (\log_a b)(\log_b c)$
cross-multiplying, $\log_b c = \dfrac{\log_a c}{\log_a b}$

Substituting e for b and 10 for a:
$\ln c = \dfrac{\lg c}{\lg e}$

But, $\log_{10} e$ is $\log_{10} 2.718 = 0.4343$

So $\ln c = \dfrac{\lg c}{0.4343}$

$\qquad = 2.3026 \lg y$

Therefore the natural logarithm of a number can be obtained by multiplying the logarithm to the base 10 by 2.3026.

We are now in a position to solve:

$i = Ie^{-Rt/L}$ (to find L).

Where $i = 0.6024A$

$\qquad I = 2A$

$\qquad t = 0.4$ seconds

$\qquad R = 9$ ohms

$\qquad 0.6024 = 2\,e^{-(9 \times 0.4)/L}$

$\qquad 0.3012 = e^{-3.6/L}$

Now we can take logs to the base 10 (or e) of both sides. Taking log to the base 10 first:

$\log_{10} 0.3012 = -\dfrac{3.6 \log_{10} e}{L}$

$-0.5211 = -\dfrac{3.6 \times 0.4343}{L}$

$L = 3$ Henrys as before.

Taking log to the base e and remembering that $\log_e e = 1$.

$-1.199 = -\dfrac{3.6}{L}$

$L = 3$ Henrys as before.

Conclusions

And so we return to what started it all in the first place, solution of the equation:

$T = t \log e \left(\dfrac{V_2}{(V_1 + V_2)} \right)$

This is now easily solved in the light of the information in the preceding text.

It can also be seen how one area of mathematics supports and re-inforces another area. For instance, although indices are not of direct relevance here, it was a good starting point for many of the proofs on logarithms.

Even a modest command of mathematics gives the electronics technician or hobbyist greater freedom to explore and exploit electronics.

Exploring Radio continued from page 46.

reading, perhaps 4-5mA. It is possible to switch now to the next range down, say 30mA FSD. Preset RV2 should be rotated clockwise until the milliammeter reads 10mA. This is the correct standing current for the receiver. This is the only setting-up as such required. The meter can now be disconnected.

If it happens that a suitable meter is not available, it will probably be reasonable, after initially setting RV2 fully anti-clockwise, to then rotate it about a quarter of its full travel in a clockwise direction. This should give a reasonable though not necessarily precise value of standing current.

All that remains now is to advance the volume control and tune in your favourite station! In the unlikely event

that no reassuring sounds issue forth from the speaker, some fault-finding will be called for. Typical values (expect slight variations in practice) of d.c. voltage levels are given on the circuit diagram. These were all measured with a 20k/V meter on the 10V d.c. range. Any faults will almost certainly be found to be due to poor quality soldered joints, including bridged tracks with excessive solder, or components either incorrectly placed or in the wrong polarity (e.g. diodes).

A Schools Project

This receiver design has been extensively tested by numerous students who have built successful models. The layout is largely non-

critical, there is no alignment to be done, and only the one setting-up procedure. It is always a source of great satisfaction to students to make something that actually does something and, even in these days of sophistication, there is genuine pleasure in building a radio receiver and then putting it to use. Details of a case design are not included but the average constructor will have little difficulty in making a suitable housing for it. Where woodwork is on the school curriculum it is possible that this project could even be made the subject of an 'integrative assignment', the cabinet being given extra appeal by being made in the traditional '30s' fretted and polished style. It's a thought anyway.

TRF MW REFLEX RECEIVER PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1	270k	1	(M270K)
R2,6	47k	2	(M47K)
R3,8	1k	2	(M1K)
R4	4k7	1	(M4K7)
R5	120k	1	(M120K)
R7	47R	1	(M47R)
R9	680R	1	(M680R)
R10,11	2R2	2	(M2R2)
RV1/S1	4k7 Switch/Pot Lin	1	(FW41U)
RV2	220R Hor. Encl. Preset	1	(UF98G)

CAPACITORS

C1,8	100µF 25V PC Electrolytic	2	(FF11M)
C2	1nF Ceramic	1	(WX68Y)
C3	470pF Ceramic	1	(WX64U)
C4	47µF 25V PC Electrolytic	1	(FF08J)
C5	10nF Ceramic	1	(WX77J)
C6	100nF Polyester	1	(BX76H)
C7	220pF Ceramic	1	(WX60Q)
VC1	Min AM Tuner	1	(FT78K)

SEMICONDUCTORS

TR1,2	BC107	2	(QB31J)
TR3	BC337	1	(QB68Y)
TR4	BC327	1	(QB66W)
D1	OA90	1	(QH71N)
D2	1N4148	1	(QL80B)

MISCELLANEOUS

L1/2	See Text	–	–
L3	Choke 4.7mH	1	(UK80B)
	Pin 2145	1 Pkt	(FL24B)
	PP3 Battery Clip	1	(HF28F)
	Speaker 64R	1	(WF57M)
	Knob K14B	2	(FK39N)
	EC Wire 0.9mm 20 swg	1 Reel	(BL26D)
	Ferrite Rod 810	1	(YG20W)
	M3 Spacer ½in	1 Pkt	(FG34M)
	Isobolt M2.5 20mm	1 Pkt	(JD15R)
	Printed Circuit Board	1	(GE15R)
	Constructors Guide	1	(XH79L)

The following part is available, but is not shown in our 1989 catalogue:

Order As GE15R (TRF Reflex PCB)
Price £3.79

DIGITAL PLAYBACK MODULE

&

EPROM PROGRAMMER CARD
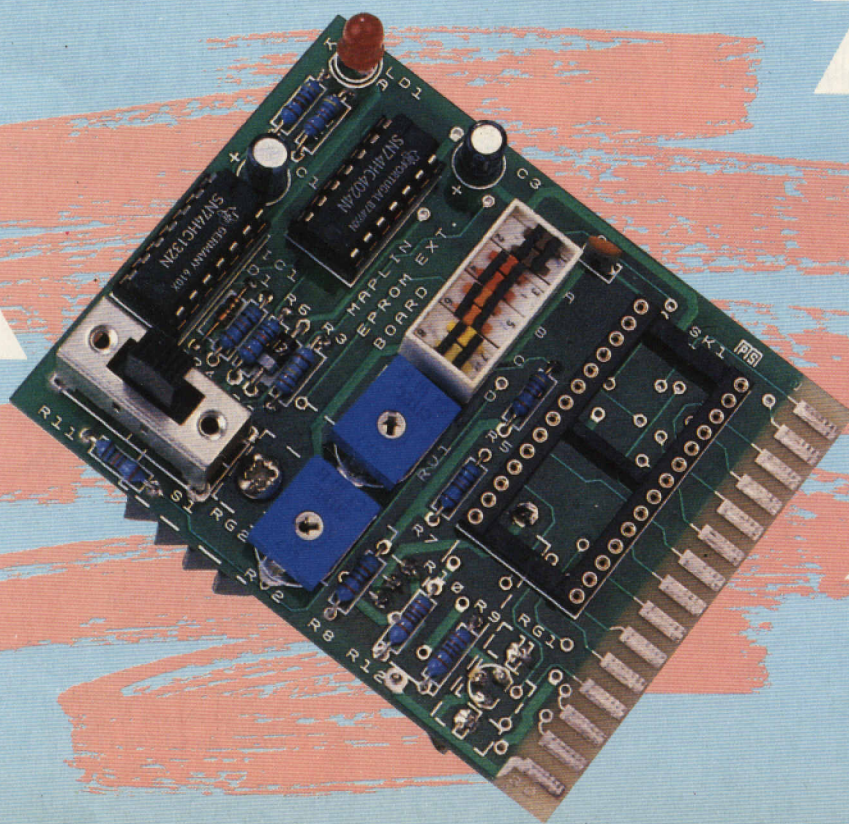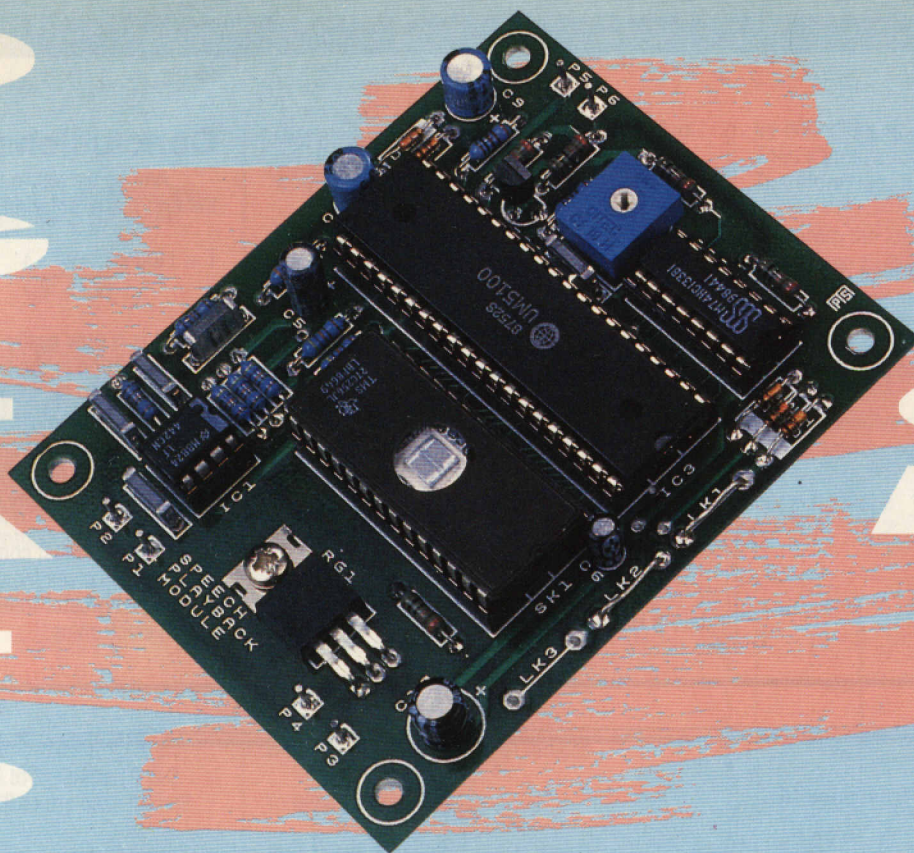
Figure 1. EPROM programmer circuit.

In the last issue of 'Electronics' construction details were given for a Digital Record and Playback module - based on the UM5100 IC - whereby speech could be digitised, stored in RAM and replayed again. The 32k static RAM supplied with the kit allowed for a maximum of 20 seconds record/play time, but had the disadvantage of 'total amnesia' once the supply voltage 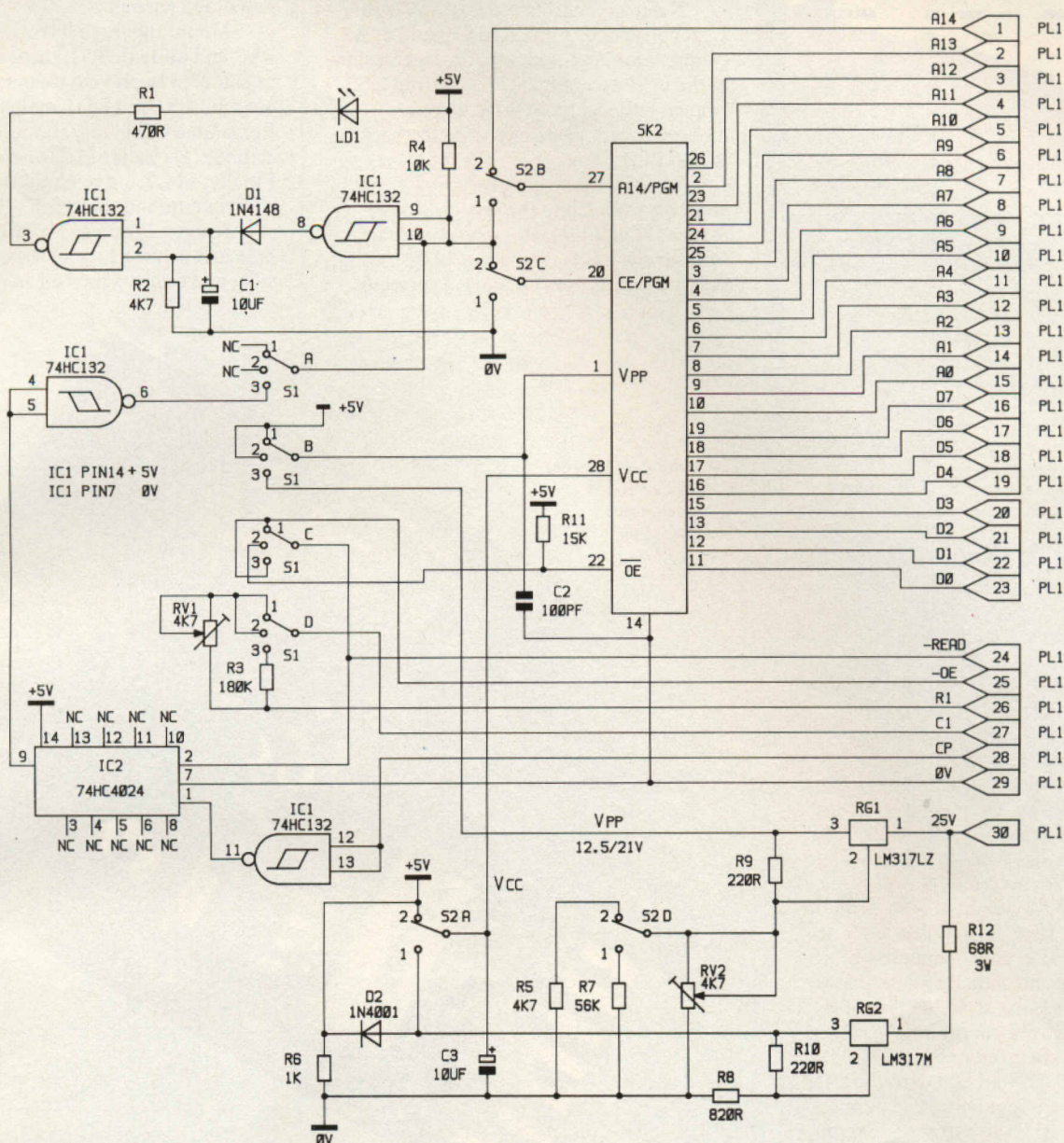was removed. This is of no consequence unless the stored data is permanently required as part of another system, such as an alarm or car annunciator. Therefore, two additional projects have been designed: an EPROM programmer for 8-32k devices and a Playback only module, which is a much reduced and simplified version of the Record/Playback module.

Programmer Circuit

The programmer circuit diagram, given in Figure 1, is able to program 8k to 32k EPROM's inserted into SK2 and also to play them back from the programmer card. Slide switch S1 selects the 'mode' required: either PROGRAM in position 3, PLAYBACK in position 2 or RECORD/ PLAY FROM RAM ONLY in position 1 (see Figure 2). Switches S2a-d are preset according to the type of EPROM being used, as can be seen in Table 1 and Figure 3.

With a simple programming system such as this, fast burn algorithms are obviously out of the question and a 20ms/50Hz (10ms burn) pulse has to be used. If a 32k EPROM is used, it will have a maximum of 20 seconds speech time, but will take 32768 x 20ms or 10.92 minutes to program! Therefore, it is impossible to program the EPROM directly while recording speech. The approach here is to set S1 to position 1 and record data directly into RAM as usual; S1 is then set in position 3 and the UM5100 made to re-play. The UM5100 now addresses the EPROM via A0 to A14, see Figure 1, and RAM data is also applied to SK2 via the D0 to D7 data bus. For successful
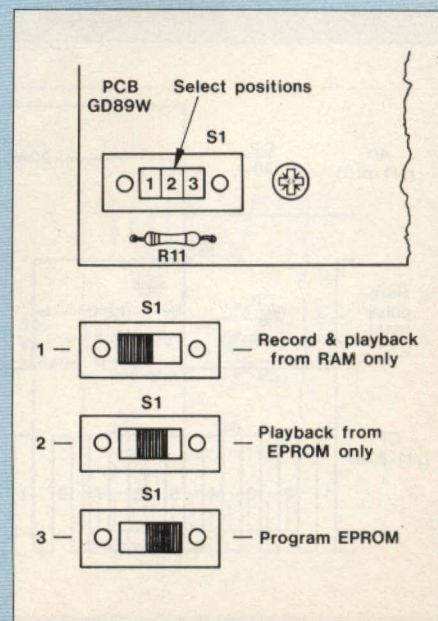
Figure 2. Select mode.

EPROM	S2a	S2b	S2c	S2d	S1	SELECT
2764						
27C64					3	
27128	2	1	1	2	To	All 3 modes
27C128					1	
27256	2	2	2	2	3	EPROM program
and	2	2	1	2	2	EPROM play
27C256	2	2	1	2	1	RAM rec/play

Table 1. Selecting EPROM type.

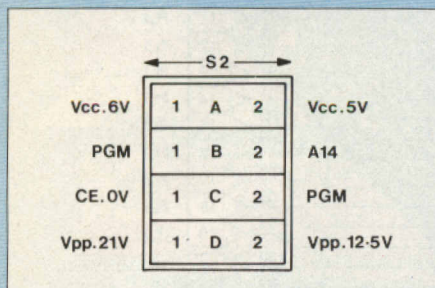|	S2			
Vcc.6V	1	A	2	Vcc.5V
PGM	1	B	2	A14
CE.0V	1	C	2	PGM
Vpp.21V	1	D	2	Vpp.12·5V

Figure 3. S2 functions.

programming, the address and data buses must be stable before the 10ms burn pulse is applied. RV2 on the rec/playback module is removed and replaced by RV1 and R3 on the EPROM card; both resistors determine the UM5100 clock pulse output at PL1 pin 28. RV1 can be adjusted for record and playback clock speeds between approximately 18us and 80us, whereas R3 is only in circuit whilst programming and fixes the clock to 2.5ms. Clock pulses are inverted by IC1 and further divided-by-eight at IC2, which generates the 10ms burn pulse at S1a and S2c. LED LD1 is only operative while programming and actually monitors the burn pulse via pulse stretcher circuit IC1, D1 and C1. Waveform timing relationships are given in Figure 4.

RV2, R5, R7 and S2d determine the voltage out from regulator RG1 (Vpp) at either 12.5 or 21V - to suit the program voltage requirement of the EPROM in use. RG2 is biased for 6V output for EPROM types that need a Vcc of 6V and a 5V rail is derived from the volt drop across D2.
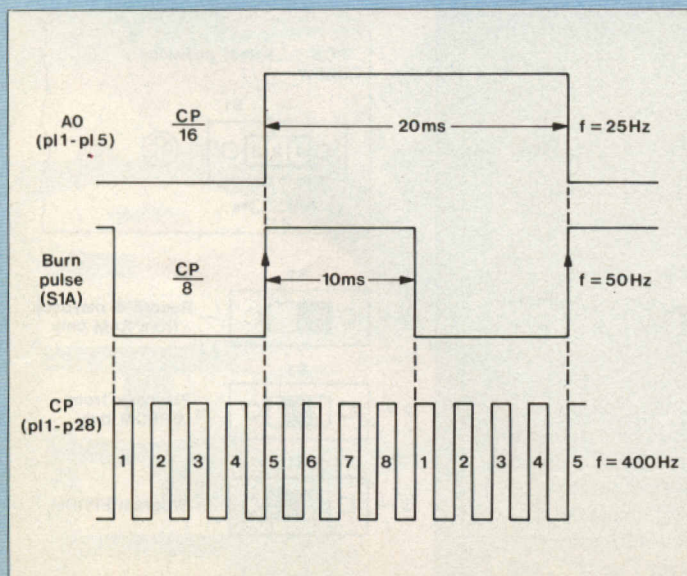
Construction

Refer to the EPROM Extension Parts List, constructors guide and Figure 5. All components are fitted onto the legend side of the PCB except for R12, RG1 and RG2 (shown dotted); these three items are mounted, with heatsinks, onto the back face of the PCB.

Identify the eleven resistors R1 to R11 and insert them into the board. Mount diodes D1 and D2, taking note of their cathode markings, and insert both polarised capacitors C1 and C3 correctly.

Solder these components and cut off the remaining wire ends.

Mount the three IC sockets, RV1, RV2 and dil switch S2; these too can now be soldered to prevent them from falling out whilst S1 and LD1 are being fitted. Remember to identify the anode (A) and cathode (K) leads of LD1 before insertion! Finally, fit C2 and re-check the components and soldering.

Insert a 12mm M3 bolt through the hole just below S1, from the component side, and tightly screw on an M3 nut. Now

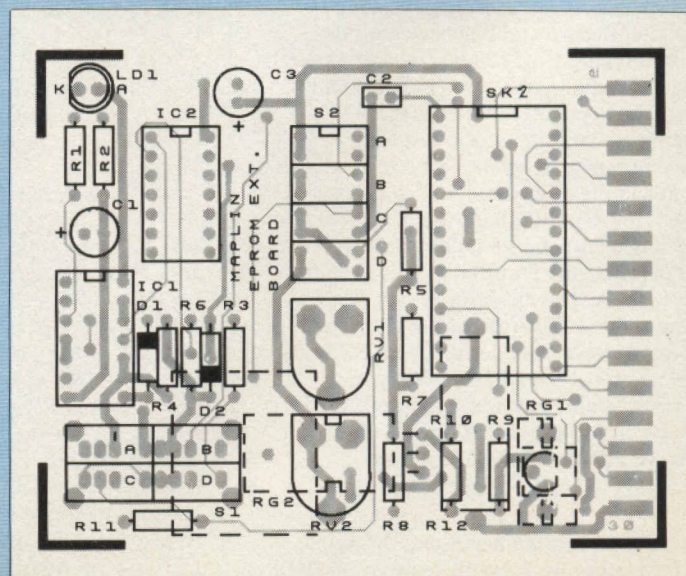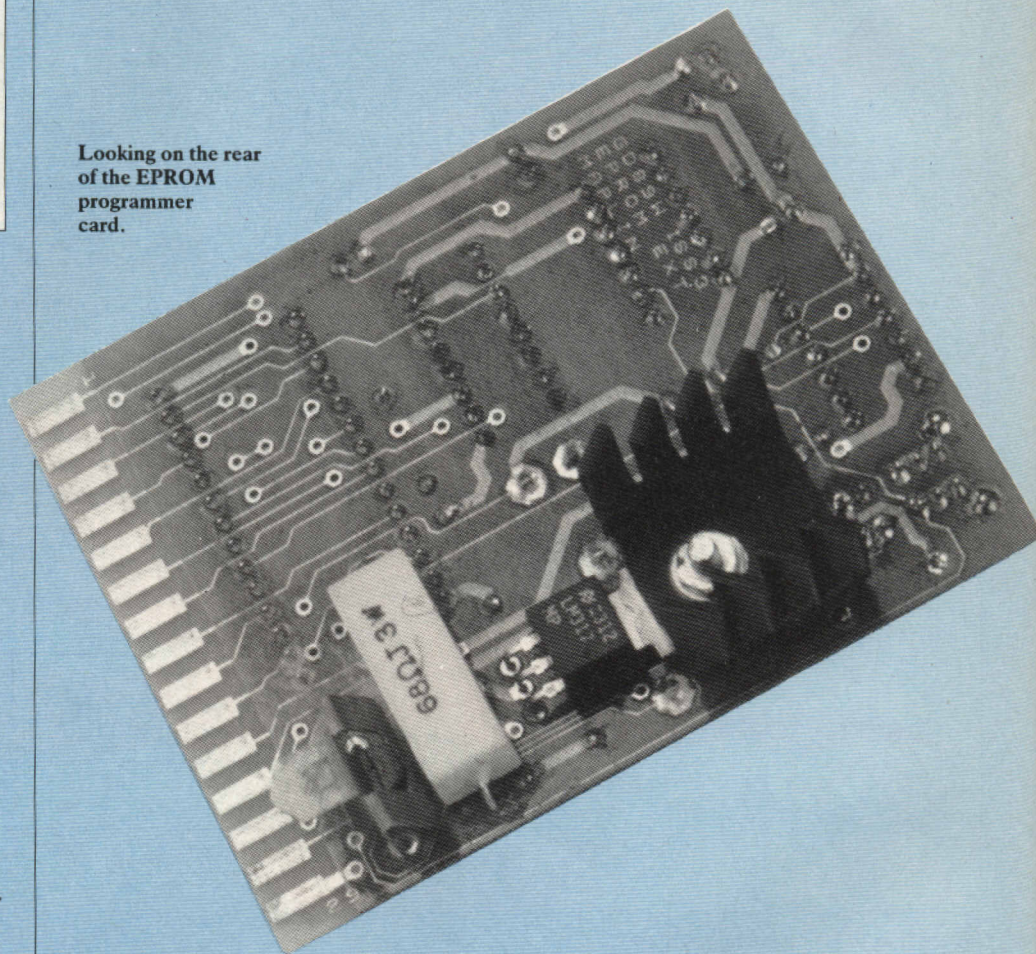**Looking on the rear of the EPROM programmer card.**

Figure 4. Programming timing.

Figure 5. Layout of programmer pcb.

Figure 6. Mounting RG2.

CORRIGENDA!

The Digital Record and Playback Module article in Feb-Mar 1989 vol. 8 issue 30 of 'Electronics' states that either an 8k byte CMOS Static RAM (SRAM), type 6264, or a 32k byte CMOS Static RAM (SRAM), type 62256, can be used in the module. This is NOT the case, only the 62256 may be used (a 62256 is supplied with the kit). Links LK2, LK3 & LK4 should all be MADE as stated in Table 1. The references to these links in this follow-on article on the EPROM module however, does still apply.
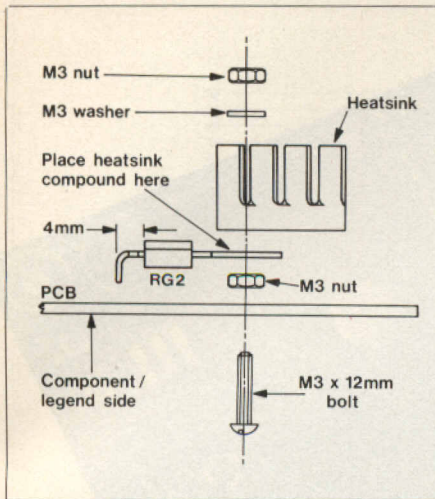
position regulator RG2 over the bolt, from the solder side as shown in Figure 6, with the chamfered edge facing outwards and away from the board; the legs are bent at right angles 4mm away from the plastic body. Spread a layer of heatsink compound over the RG2 tab and fit the vaned heatsink and M3 washer and nut. Solder RG2 from the opposite, component, side (between R8 and R12).
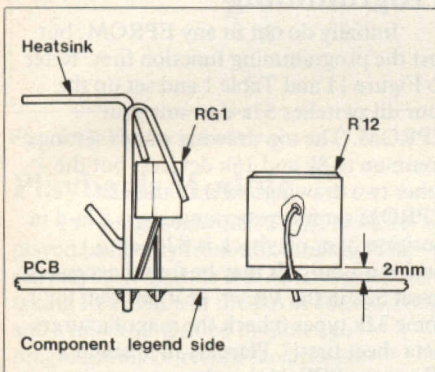

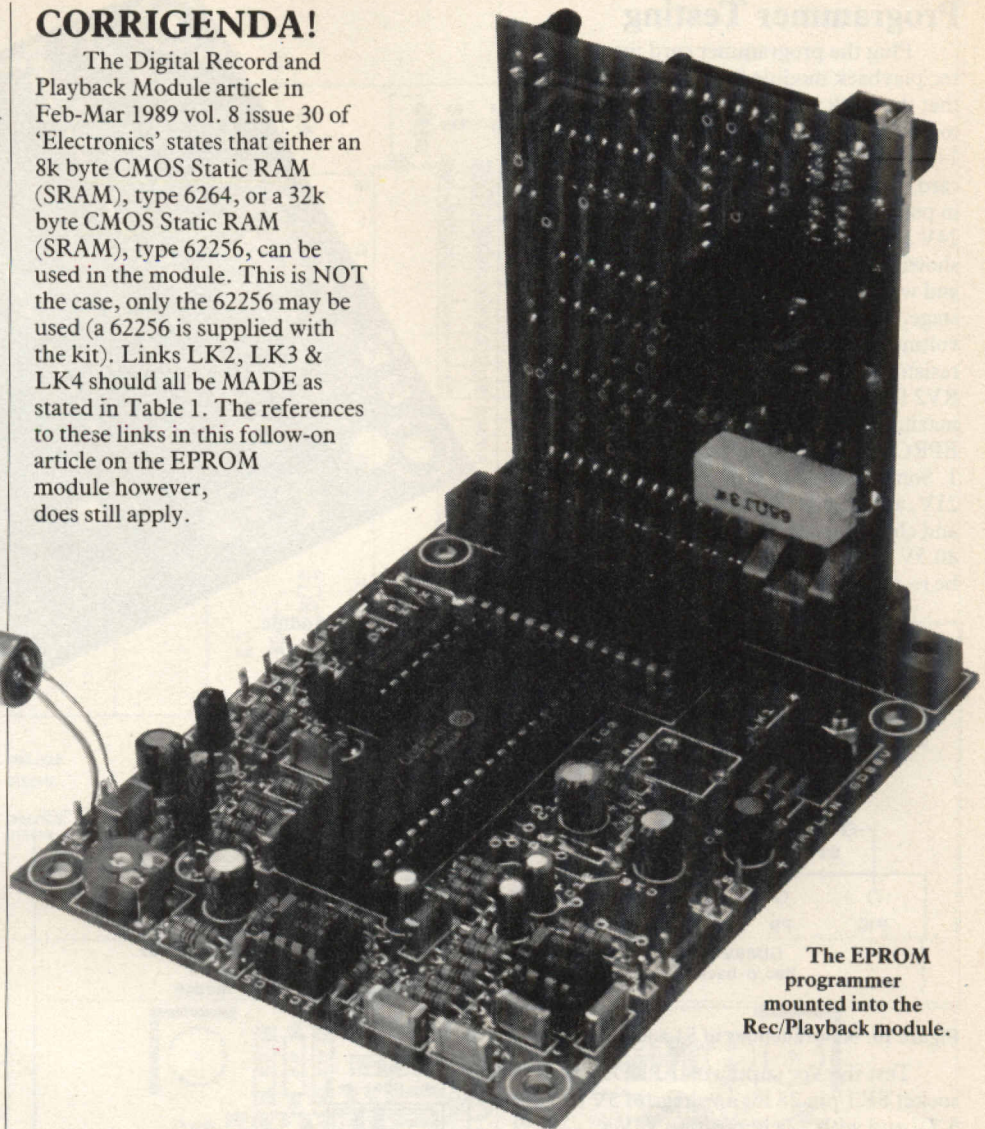**Figure 7. Mounting RG1 and R12.**

Next, fit the rectangular 3W resistor R12 on the same side as - and just below - RG2; allow 2mm clearance between the resistor and PCB and solder both leads from the same (track) side. The plastic TO92 regulator RG1 is also mounted from this side, but first it should be fitted into the clip-on heatsink and then both RG1 and heatsink are inserted into the PCB as shown in Figure 7. This time, solder both heatsink legs and the three RG1 leads from the front component side and remove excess wire ends. When complete the back mounted components should resemble those shown in Figure 8.

Rec/Playback Module Modifications

A 2 x 15 way socket (SK1) is fitted to the component side of the Record & Playback module (board number GD88V) and this is where the EPROM module plugs in. Solder the thirty terminal pins on SK1 to this board and also remove RV2 and wire link LK1, if fitted earlier. LK1 previously joined the UM5100 READ line to the RAM IC5. Now READ is extended

The EPROM programmer mounted into the Rec/Playback module.
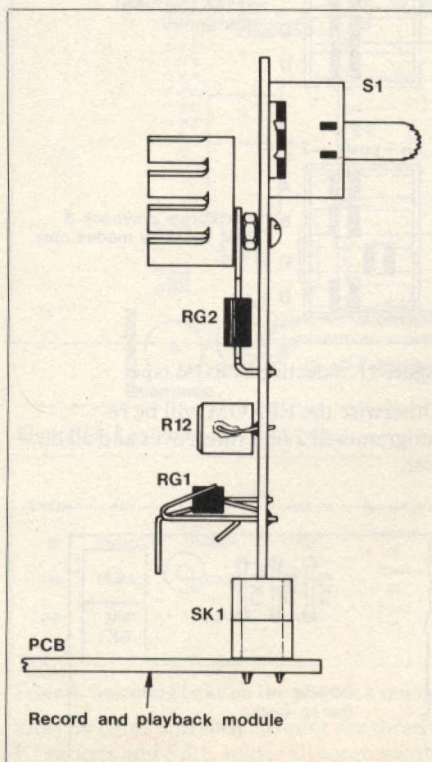

Figure 8. Inserting programmer into rec/playback module.

via SK1 pin 24 to switch S1 and IC2 and RV2 is replaced by RV1 and R3 on the EPROM module, as previously mentioned in the circuit description.

Note: RV2 and LK1 will have to be replaced if the rec/playback module is to be used again without the EPROM module fitted!
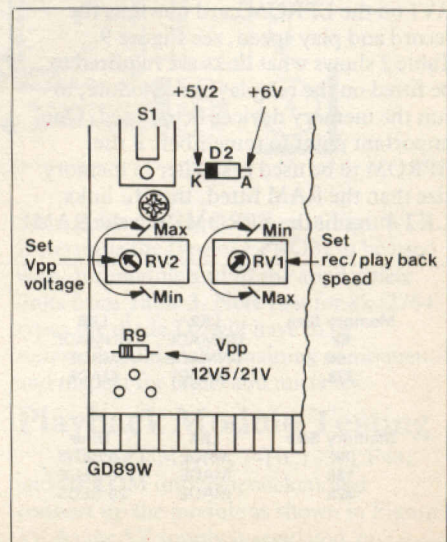

Figure 9. Testing the programmer.

Programmer Testing

Plug the programmer card into the rec/playback module SK1, orientated such that the track solder side faces inwards - towards the UM5100. Place S1 in position 1 (towards the top edge of the programmer card) and ensure all four switches on S2 are in position 2 (towards SK1). Connect a 24V DC power supply and amplifier as shown in Figure 7 of the previous article and without an EPROM fitted at this stage, turn on the supply and connect a voltmeter to one of the 0V pins and Vpp at resistor R9 as shown in Figure 9. Adjust RV2 for a reading of 12.5V to 12.8V maximum; this is the Vpp for all six EPROM's recommended for use in Table 1. Some EPROM's require a higher Vpp of 21V, and in that case set S2d in position 1 and check for a voltage reading between 20.5V and 21V. Either of these Vpp's can be re-adjusted from RV2 as required.
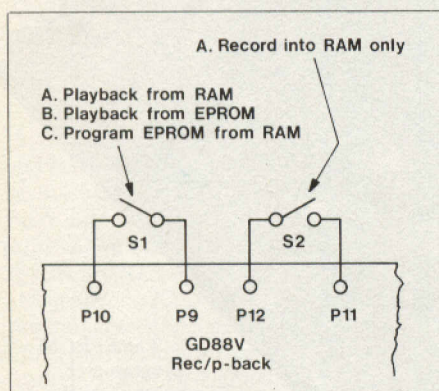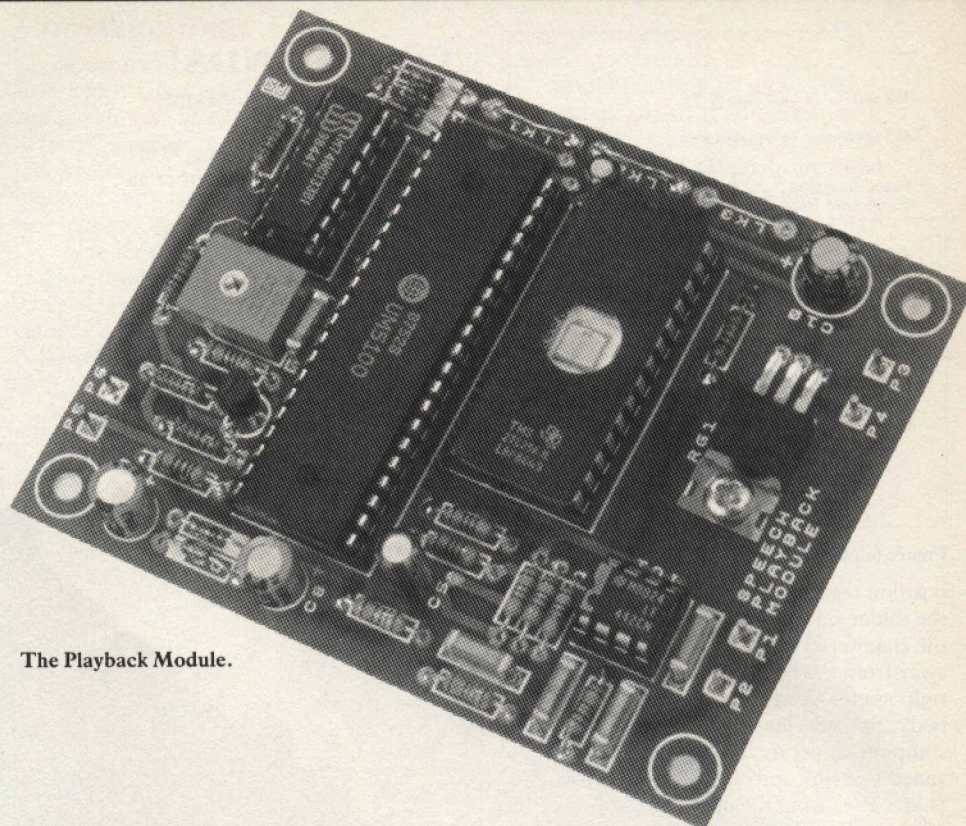
The Playback Module.

Figure 10. New functions of S1 and S2.

Test the Vcc supply on EPROM socket SK1 pin 28 for a voltage of 5V to 5.3V and with S2a in position 1, Vcc should be 5.8V to 6.2V (this test can also be made from D2). The various voltage readings will obviously vary slightly from those given here, according to component tolerances and meter accuracy, etc.

With S1 still in position 1, record some speech by momentarily connecting pins 11 & 12 (record) together and speaking into the microphone and then check the playback from RAM is alright. RV1 on the EPROM card now sets the record and play speed, see Figure 9. Table 2 shows what links are required to be fitted on the rec/playback module, to suit the memory devices being used. One important point to remember: if the EPROM to be used is smaller in memory size than the RAM fitted, then fit links LK2-4 to suit the EPROM - not the RAM!
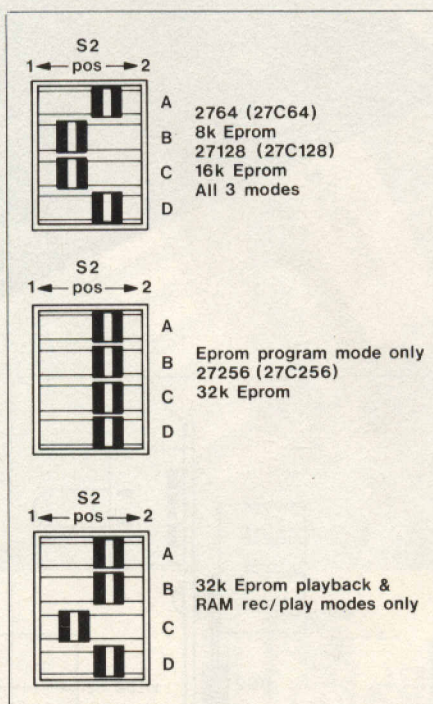

Figure 11. Selecting EPROM type.

Otherwise the EPROM will be re-programmed 2 or 3 times over and all data lost.

Programming

Initially do not fit any EPROM, but test the programming function first. Refer to Figure 11 and Table 1 and set up the four dil switches S2a-d to suit your EPROM. The top drawing shows settings common to 8k and 16k devices, but the other two drawings refer to the 32k EPROM set for: programming is S2a-d in position 2, or playback is S2c set to position 1 only. It may be found necessary to set S2a in the Vcc = +6V position for some 32k types (check the manufacturers data sheet first!). Place S1 in position 3 (Program EPROM) and momentarily connect pins 9 and 10 (playback) together. The contents of RAM are output at a much slower speed, due to the EPROM programming timing requirements, and this results in a sequence of bleeping and popping from the audio amplifier. During programming only LED LD1 should be on, although LD1 on the rec/playback module may also flicker as well. If you have access to an oscilloscope, then the various timing waveforms in Figure 4 can be checked.

At the end of the programming sequence LD1 will go out. You can calculate the time taken to program an EPROM in minutes by: memory size (in bytes) x 0.02/60 and times vary from 2.5 to 11 minutes according to the EPROM type.

Turn off the power to the modules and insert your EPROM. Re-check S2 settings, place S1 in position 1 and power up the modules again. Record some suitable information in RAM and then program the EPROM by switching S1 to position 3 and starting the playback/program sequence as mentioned earlier. Once programming is complete, place S1 (and S2c if applicable) in position 2 to playback (verify) from EPROM only.

Memory Size	LK2	LK3
8k	UNMADE	UNMADE
16k	UNMADE	MADE
32k	MADE	MADE

Memory Size	LK4	Time
8k	MADE	5 SECS
16k	MADE	10 SECS
32k	MADE	20 SECS

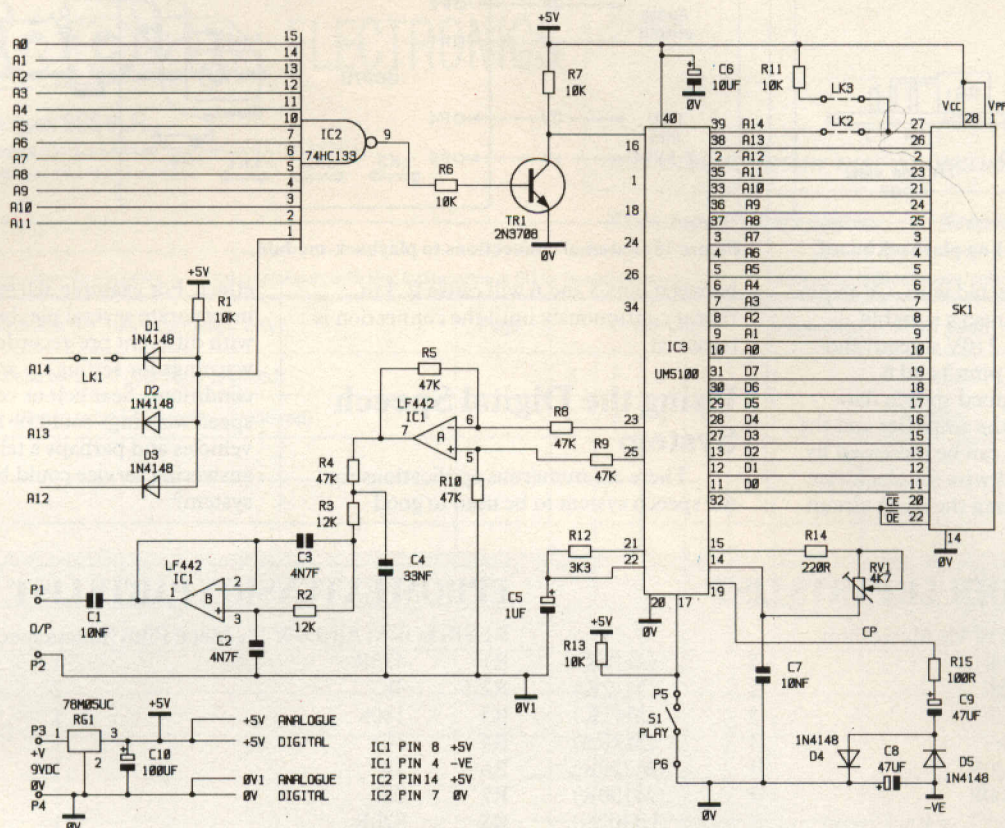Table 2. Selecting links on the rec/playback module.

Figure 12. Playback module circuit.

Playback Module

Pre-programmed EPROM's can be played back only from this module. The rec/playback module was not designed for taking EPROM's in the RAM socket (IC5) and a much simplified module (no programming or record facilities) is available for playback only. The circuit diagram for the playback module, Figure 12, is very similar to that of Figure 2 in the previous article (refer to issue No.30). Connecting pins 5 and 6 together places the UM5100 in playback mode and the EPROM fitted in SK1 is enabled (IC3 pin 32) and accessed over the address bus A0 to A14. Data from the EPROM is then READ by the UM5100, on D0 to D7, and changed from digital data to an analogue signal (D to A conversion) at IC1a. Clock pulses and unwanted conversion noise signals are removed by the low pass filter IC1b, ready to be connected from pin 1 (output) and pin 2 (0V) to the input of a suitable amplifier. The average signal output from pin 1 is about 50mV.

Construction

Assembly of this module is very straightforward and no difficulties should be encountered. Refer to Figure 13 and fit six veropins into pin 1 to pin 6 positions - inserted from the track solder side first. Push home with a hot soldering iron and solder in position. Identify and mount the resistors, diodes and capacitors; C5, 6, 8 to C10 are polarised electrolytics and
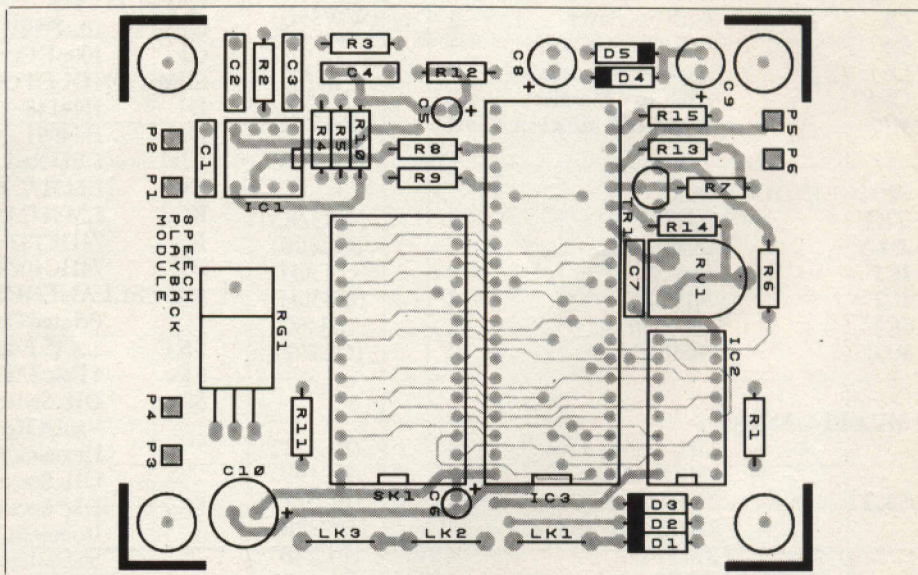
Figure 13. Layout of playback pcb.

Table 3. Selecting links on the playback module.

EPROM	LK1	LK2	LK3	Remember
8k	UNMADE	UNMADE	MADE	Remove D2
16k	UNMADE	UNMADE	MADE	Insert D2
32k	MADE	MADE	UNMADE	Insert D2

must be fitted correctly. Mount the three IC sockets and SK1, solder all components in place on the board and remove excess wire ends. Insert TR1, RV1 and assemble

the regulator RG1, as shown in Figure 14. Determine the type of EPROM to be used with this module and fit the appropriate links from Table 3. Note that for 8k (2764) types the diode D2 will have to be removed. Solder all remaining components and inspect for faults and mistakes.

Playback Module Testing

Fit the UM5100, 74HC133, LF442 and EPROM into their sockets and connect up the module as shown in Figure 15. As the 5V supply is regulated 'on board' you will require a power supply of
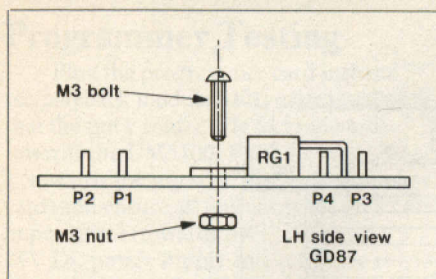
Figure 14. Mounting RG1 on playback board.

Figure 15. External connections to playback module.

at least 7.5V DC connected with +V to pin 3 and 0V to pin 4. Connect a suitable power amplifier to pin 2 (0V screen) and pin 1 and short circuit pins 5 and 6 together. Pre-programmed speech data should be heard from the amplifier and the 'pitch' or replay speed can be increased by rotating RV1 anti-clockwise (or clockwise to decrease). Maintaining the short circuit between pins 5 and 6 will cause IC3 to repeat continuously until the connection is removed.

Using the Digital Speech System

There are numerous applications for the speech system to be used to good effect. For example alarm systems could incorporate several playback modules, with different pre-recorded messages or warnings for setting up and alarm conditions. Seat belt or verbal fuel and speed warnings could be installed in motor vehicles and perhaps a telephone answering service could be based on this system?
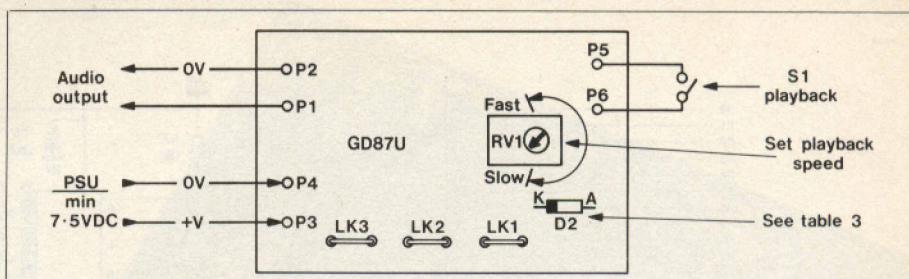
PLAYBACK MODULE PARTS LIST

RESISTORS: All 0.6W 1% Metal Film

R1,6,7,11,13	10k	5	(M10K)
R2,3	12k	2	(M12K)
R4,5,8,9,10	47k	5	(M47K)
R12	3k3	1	(M3K3)
R14	220R	1	(M220R)
R15	100R	1	(M100R)
RV1	4k7 Hor Encl Preset	1	(UH02C)

CAPACITORS

C1,7	10nF Polylayer	2	(WW29G)
C2,3	4n7F Polylayer	2	(WW26D)
C4	33nF Polylayer	1	(WW35Q)
C5	1μF 63V Minelect	1	(YY31J)
C6	10μF 16V Minelect	1	(YY34M)
C8,9	47μF 16V Minelect	2	(YY37S)
C10	100μF 16V Minelect	1	(RA55K)

SEMICONDUCTORS

TR1	2N3708	1	(QR32K)
D1-5	1N4148	5	(QL80B)
IC1	LF442	1	(QY30H)
IC2	74HC133	1	(UB30H)
IC3	UM5100	1	(UJ48C)
RG1	78M05UC	1	(QL28F)

MISCELLANEOUS

	DIL Socket 8 Pin	1	(BL17T)
	DIL Socket 16 Pin	1	(BL19V)
SKT1	DIL Socket 28 Pin	1	(BL21X)
	DIL Socket 40 Pin	1	(HQ38R)
	Pin 2145	1 Pkt	(FL24B)
	TC Wire 0.71mm 22swg	1 Reel	(BL14Q)
	Isobolt M3 × 6mm	1 Pkt	(BF51F)
	Isonut M3	1 Pkt	(JD61R)
	P.C. Board	1	(GD87U)
	Constructors Guide	1	(XH79L)

OPTIONAL

S1	Push Switch	1	(FH59P)

The above items, excluding Optional, are available in a kit:
Order As LM85G (Playback Kit) Price £14.95
The following item is available separately:
Playback PCB **Order As GD87U Price £6.50**

EPROM EXTENSION PARTS LIST

RESISTORS: All 0.6W 1% Metal Film (unless specified)

R1	470R	1	(M470R)
R2,5	4k7	2	(M4K7)
R3	180k	1	(M180K)
R4	10k	1	(M10K)
R6	1k	1	(M1K)
R7	56k	1	(M56K)
R8	820R	1	(M820R)
R9,10	220R	2	(M220R)
R11	15k	1	(M15K)
R12	68R 3W Wirewound	1	(W68R)
RV1,2	4k7 Hor Enclosed Preset	2	(UH02C)

CAPACITORS

C1,3	10μF 50V P. C. Electrolytic	2	(FF04E)
C2	100pF Ceramic	1	(WX56L)

SEMICONDUCTORS

D1	1N4148	1	(QL80B)
D2	1N4001	1	(QL73Q)
LD1	LED Red	1	(WL27E)
RG1	LM317LZ	1	(RA87U)
RG2	LM317M	1	(RA86T)
IC1	74HC132	1	(UB29G)
IC2	74HC4024	1	(UF01B)

MISCELLANEOUS

	Printed Circuit Board	1	(GD89W)
SK1	2 × 15 Edge Connector 0.156in	1	(JB63T)
S1	4 Pole 3 Way Slide Switch	1	(FH38R)
S2	DIL Switch SPDT Quad	1	(XX29G)
	Vaned Heatsink	1	(FL58N)
	Heatsink 92F	1	(HQ79L)
	DIL Socket 14 Pin	2	(BL18U)
SK2	DIL Socket 28 (Turned Pin)	1	(FJ68Y)
	Isobolt M3 × 12mm	1 Pkt	(BF52G)
	Isowasher M3	1 Pkt	(JD76H)
	Isonut M3	1 Pkt	(BF58N)
	Silicone Grease Tube	1	(HQ00A)
	Constructors Guide	1	(XH79L)

OPTIONAL

	2764 EPROM	1	(QQ09K)
	27C64 EPROM	1	(UH43W)
	27128 EPROM	1	(YH88V)
	27C128 EPROM	1	(UH95D)
	27256 EPROM	1	(QY75S)
	27C256 EPROM	1	(UH44X)

The above items, excluding Optional, are available in a kit:
Order As LM86T (EPROM Ext. Kit) Price £14.95
The following item is available separately:
EPROM Ext. PCB **Order As GD89W Price £5.99**

COMPUTER *Graphic* EQUALiSER

REMOTE CONTROL

Reviewed by Robert Ball A.M.I.P.R.E.

- ★ Infra-red Remote Control Unit for Armchair Control
- ★ 12-band Equaliser/Spectrum Analyser
- ★ Manual or Automatic Room Acoustics Adjustment
- ★ Four Memories to Store and Recall Equaliser Set-ups
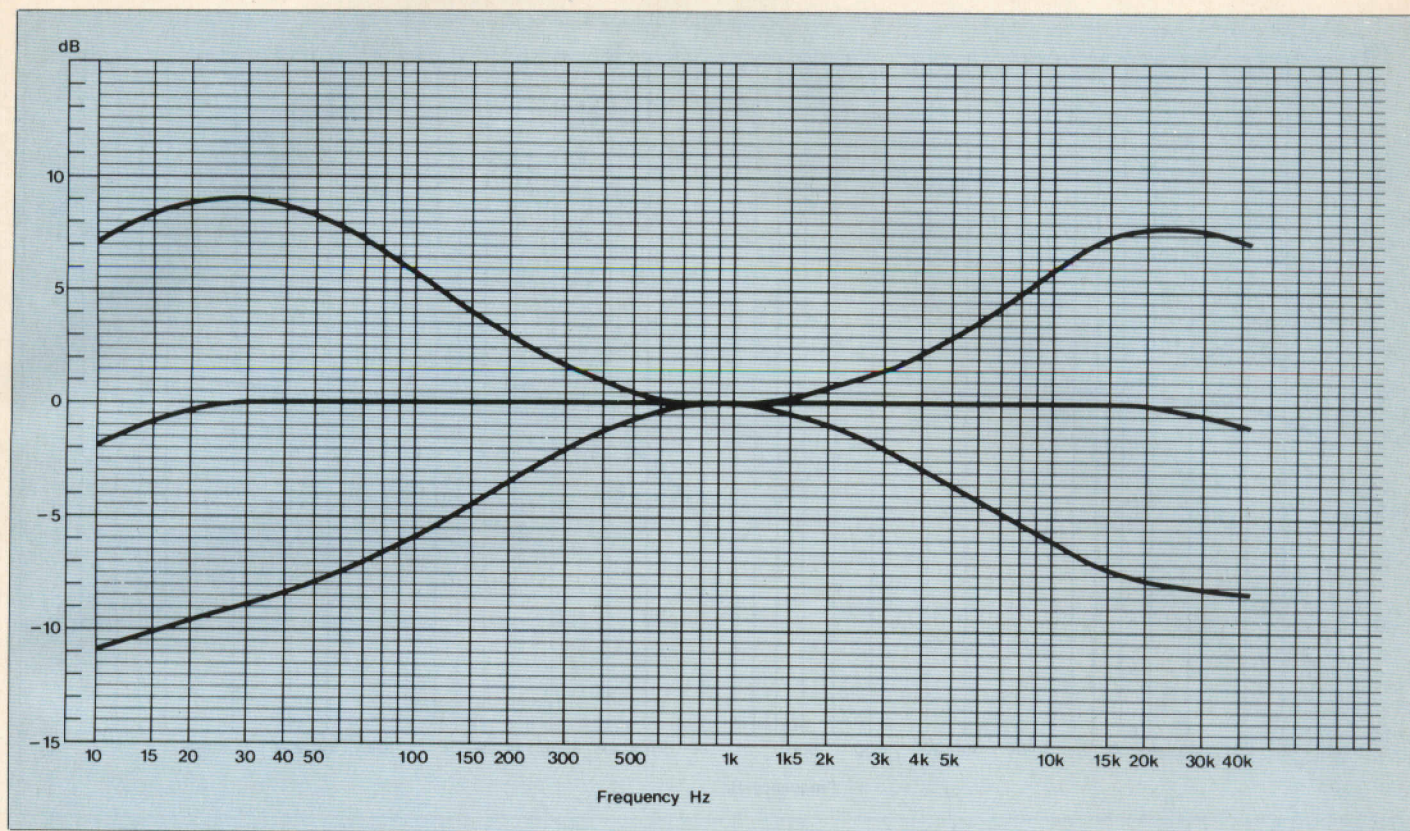- ★ Full Monitoring and Dubbing Facilities

Figure 1. Baxandall tone control response.

Introduction

A quick glance through the Entertainment section of the 1989 Maplin catalogue reveals one of the latest additions to their range of hi-tech audio products; the XM01B Computer Graphic Equaliser with Remote Control.

This superb graphic equaliser features a host of functions to satisfy the most discerning of music listeners, who demand flexibility of their Hi-Fi without having to resort to 'diving round the back' to move plugs around.

The equaliser has twelve bands of adjustment on each channel to allow you to tailor the sound of your Hi-Fi to just how you want it, this means you are able to compensate for deficiencies in room acoustics. The average front room is invariably far from ideal in terms of the perfect listening environment, with a mixture of hard walls and soft furnishings which tend to 'colour' the sound.

Most equalisers are adjusted from the front panel with a set of slide potentiometers, the position of which shows graphically the equalisation curve; hence the name, Graphic Equaliser. The XM01B differs in that the adjustments are made by up/down (boost/cut) buttons and the equalisation is displayed on a LED bargraph display on the front panel. The display also doubles as the spectrum analyser display, which shows the relative amplitudes of the frequency bands.

The best place to adjust the equaliser controls is from the listening position and as most Hi-Fi systems are tucked in the corner of the room, this is not usually possible. But, with the XM01B this is possible, as it features an infra-red remote control unit, which duplicates the major functions on the front panel, allowing full control from the comfort of your favourite armchair!

What is an Equaliser?

In its simplest form, an equaliser may be just a set of tone controls, as commonly found on the front of an amplifier. The two controls, treble and bass, allow control of two areas of the sound range, high pitch sounds and low pitch sounds, whilst the middle range is left almost unaffected. The controls can be adjusted to either boost or cut the high and low pitch sounds as required. The nominal, overall frequency range is 20Hz to 20KHz. Figure 1 shows the response of a typical Baxandall type, treble/bass tone control. The range of frequencies that each control covers is deliberately set quite wide, this is so that the effect is gradual, rather than a sharp peak in the response, which would sound unnatural. For general use this simple treble/bass tone control may be sufficient to cater for personal taste in how the music sounds.

There is also another need for equalisation; that is to compensate for the listening environment and to compensate for the equipment being used to reproduce the sound. Ideally both the room and the equipment should have a flat frequency response, i.e. so that all frequencies are heard as equal intensity (providing your hearing is not damaged or impaired). With modern amplifiers and music sourced from a Compact Disc Player the weakest links in the chain are likely to be the room and the speakers. These will have certain frequencies at which they either increase or decrease the level reproduced. Soft furnishings absorb higher frequencies and small speakers tend to have a poorer lower frequency response than larger speakers (again modern technology is playing an important part in continuing to improve the sound of small speakers). At some frequencies some objects may even vibrate, this is because the sound source is at the natural resonant frequency of the object, and quite often shows up as a door to a room vibrating. This can happen at suprisingly low volume levels and is very annoying!

Specifications
MAIN UNIT
Frequency Response : <20Hz to 150kHz
Total Harmonic Distortion : 0.009% at 1V
RMS, 20Hz to 20kHz
Signal to Noise Ratio : 90dB (IHF)
Overall Gain : 0dB
Input Impedance : 50kΩ
Output Impedance : <600Ω
Centre Frequencies : 25Hz, 40Hz, 63Hz, 100Hz, 160Hz, 250Hz, 500Hz, 1kHz, 2kHz, 4kHz, 8kHz, 16kHz

Bandwidth : 1 Octave
Control Range : ± 10dB
Level Indicator Sensitivity : 750mV
Spectrum Analyser Sensitivity : 130mV
Pink Noise Output Level : 150mV
Power Requirements : 240V AC 50Hz 25W
Dimensions : 420 x 88 x 220mm deep
Optimum Signal Level (for lowest noise & distortion) : 1V to 3V RMS

REMOTE CONTROL UNIT
Power Requirements : Two AA size batteries (not supplied)
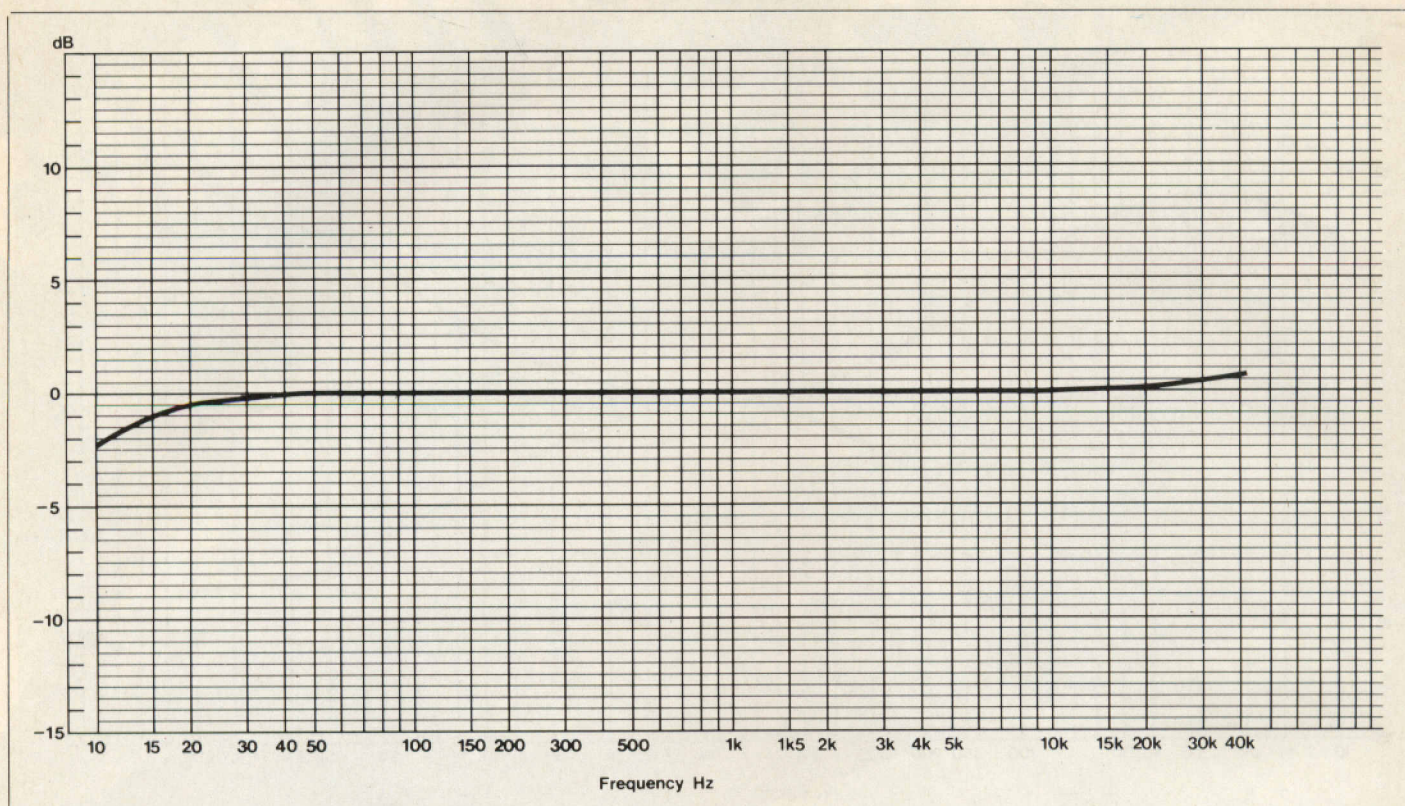Dimensions : 170 x 64 x 19mm thick

Figure 2a. Flat response.

For these reasons, a simple tone control system is not selective enough, what is needed is finer control of narrower bands of the frequency range. This is where the graphic equaliser comes into play, it basically consists of a number of frequency selective networks, each of which are tuned to allow adjustment of a narrow band of frequencies. As with normal tone controls the same boost/cut arrangement applies. The greater the number of bands or sub-divisions the finer the degree of control. With this arrangement compensation can be applied to the signal to boost or cut the necessary areas to achieve as near a flat response as possible. Figure 2a shows the response of the equaliser when set 'FLAT'. Figure 2b shows 6dB boost/cut at 100Hz. Figure 2c shows 6dB boost/cut at 1kHz. Figure 2d shows 6dB boost/cut at 8kHz.

It must be said, however, that setting up the equalisation should be done carefully to avoid making things worse than they were to start off with!

Golden Rules of Equalising

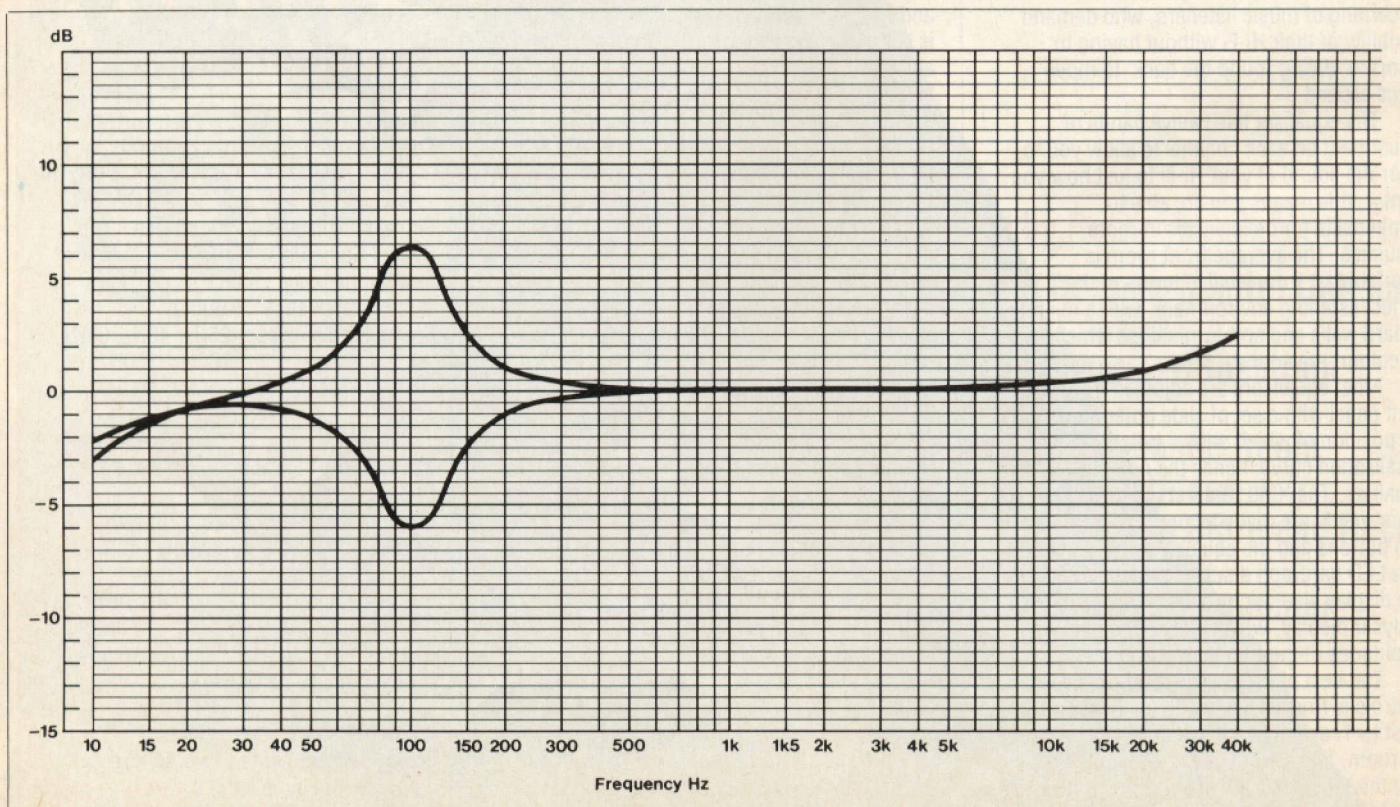A few 'golden rules' apply to equalising for room and speakers:

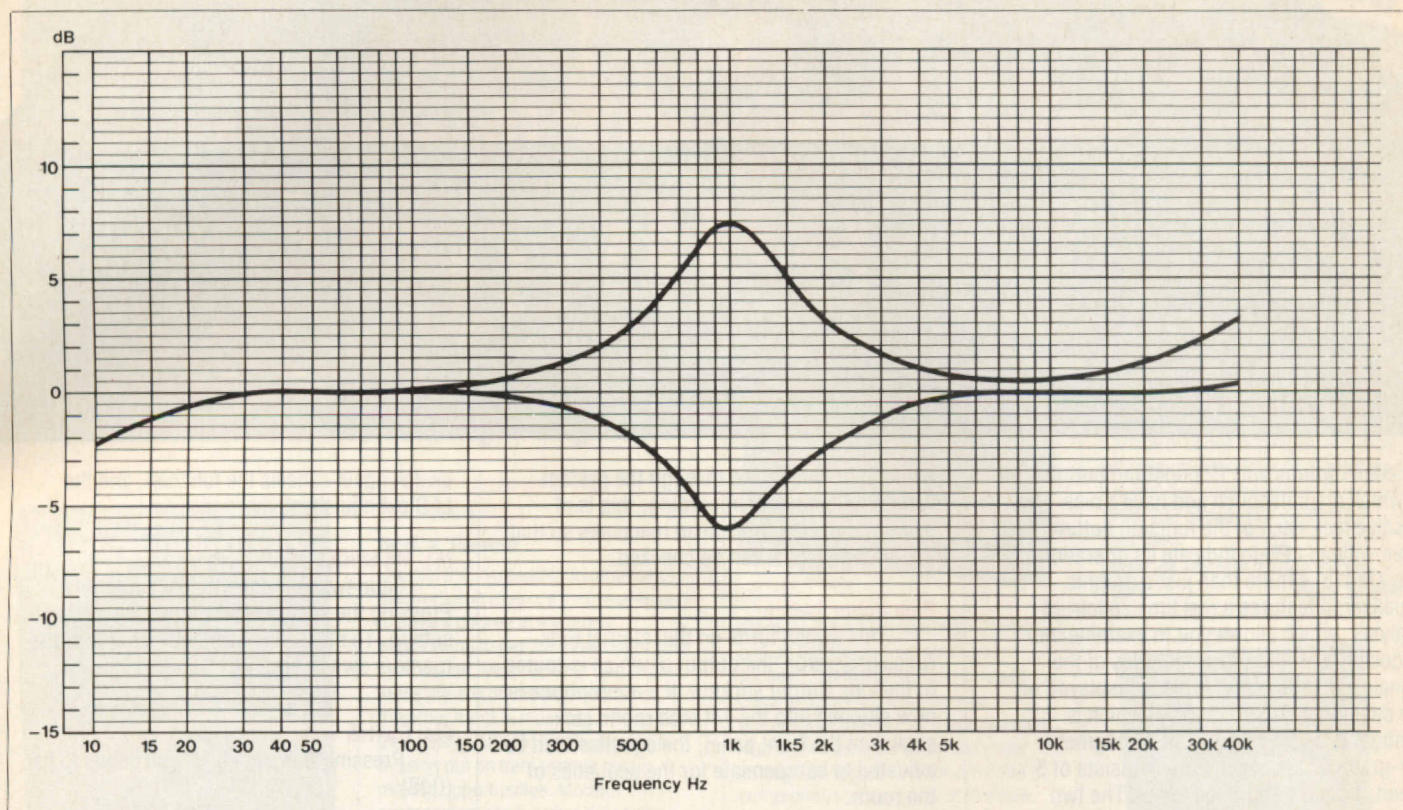**Figure 2b. 6dB boost/cut at 100Hz.**
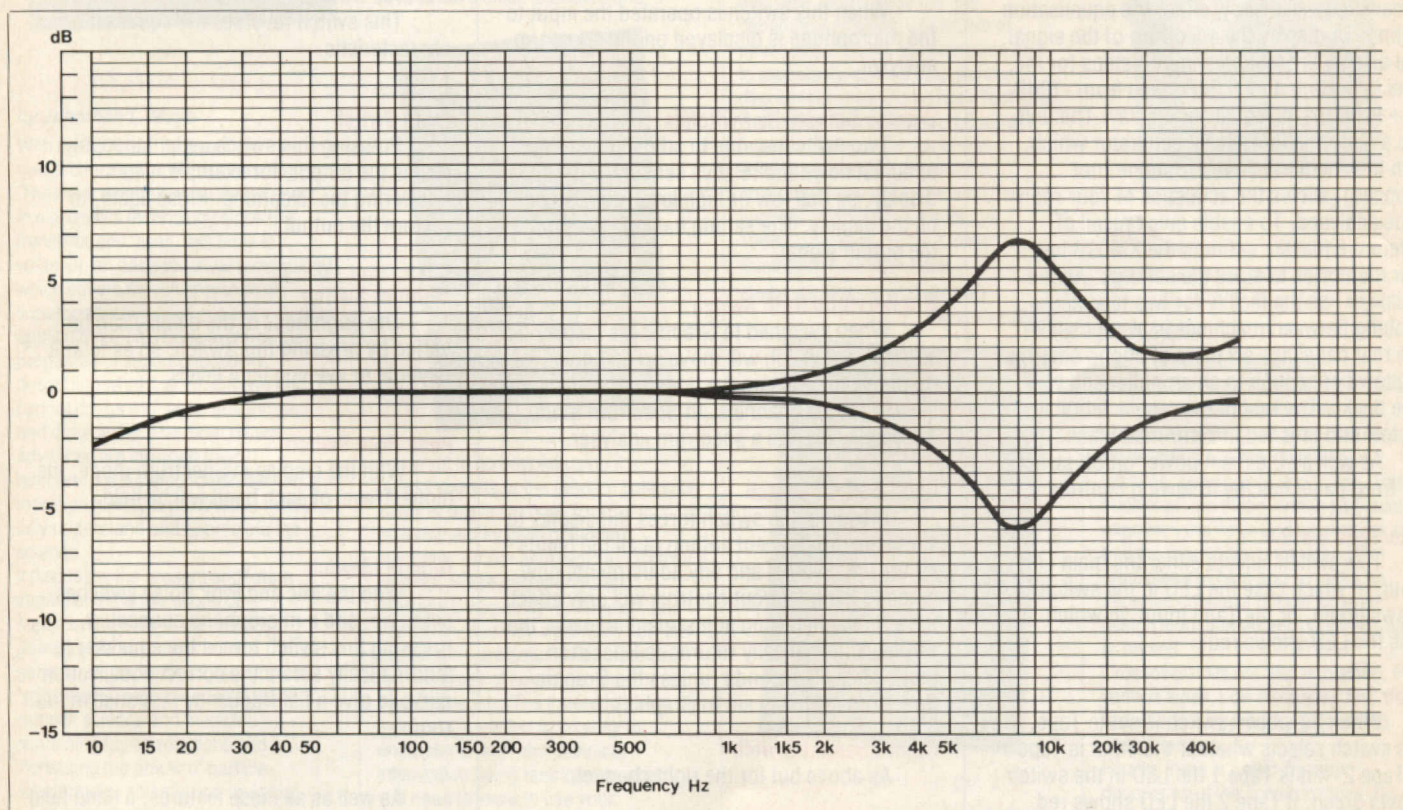
Figure 2c. 6dB boost/cut at 1kHz.

Figure 2d. 6dB boost/cut at 8kHz.

1) Set up the equipment properly and spend as much time as possible on sensible positioning of the speakers, so as to get the sound as good as possible BEFORE any equalisation is applied. Read the makers recommendations on positioning the speakers, i.e. floor, wall or bookshelf, also moving the speakers a matter of a few feet can make the world of difference.

2) Set the tone controls to flat and turn off the loudness button if your amplifier has one, this is so that the equaliser is not 'fighting' the tone controls.

3) Start with the equaliser set flat and make as small adjustments as is necessary, avoid having very high levels of boost or cut, this will sound very unnatural.

4) Don't try to get the impossible out of speakers! Trying to get a pair of small bookshelf loudspeakers to sound like 18 inch Monitors by applying a lot of low frequency boost is likely to produce a sound which is muddy and could even damage the speakers/amplifier. The same applies with the very high frequencies.

Controls and Facilities

The XM01B is solidly built and attractively styled with a black anodised aluminium front panel. There are 26 main
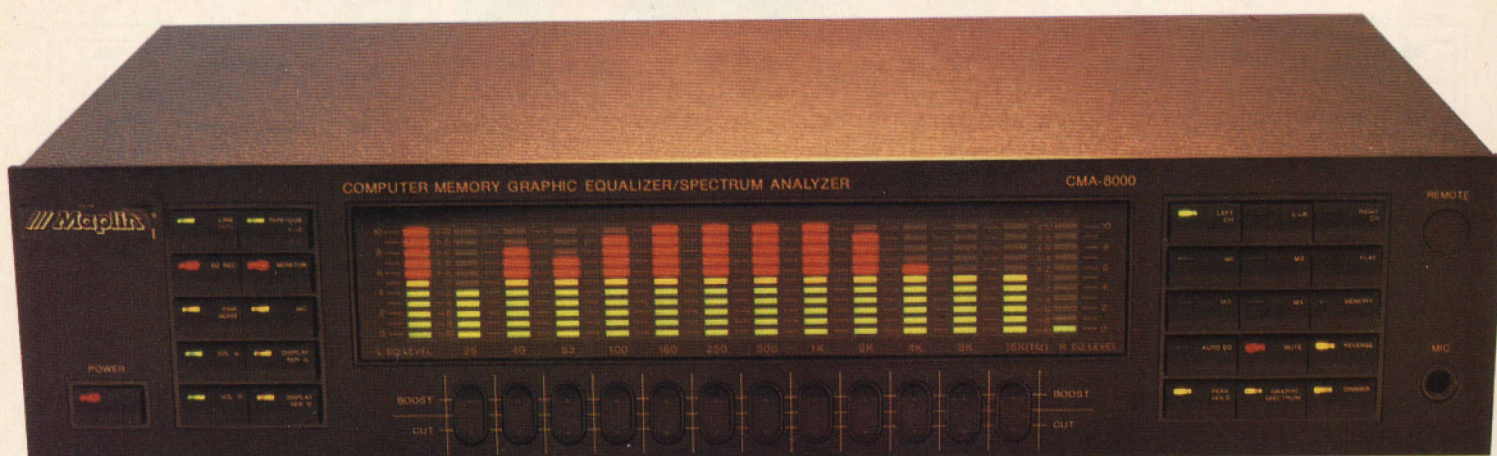
function buttons and 12 boost/cut buttons, all of which are soft-touch and have a nice positive feel, each of the function buttons are fitted with an LED to indicate its operation. The XM01B is more than just a graphic equaliser; it features a real time spectrum analyser, which allows you to examine the frequency content and amplitudes of the signals it is processing. This is displayed on the dual function LED display, which is configured as 14 columns of 11 segment bar-graph arrays. Each array consists of 5 green, 1 yellow and 5 red LEDs. The two outermost displays show the overall signal levels of the left and right channels, whilst the remaining twelve show either the equalisation settings or display the spectrum of the signal. The display is graduated in 1dB steps for the level indicators and in 2dB steps from -10dB to +10dB for the equaliser display. The unit has an internal Pink Noise generator which, with the addition of a microphone (not supplied), allows the acoustics of your room to be analysed. To enable quick recall of different equaliser settings the XM01B has four memories to store the settings. As the equaliser has the facility for two tape decks, dubbing between machines is also possible. The rear panel has six pairs of phono sockets to allow connection to an amplifier and two tape decks. The rest of the case is fabricated in steel and finished in semi-matt black.

As well as the main power on/off switch, the front panel has the following controls:

Line/Tape Switch
This switch selects either the main Line Input, in which case the LED in the switch shows green, or the Tape Input, in which case the LED shows red.

Tape 1/2 Switch
When the above switch is set to Tape, this switch selects whether the input is Tape 1 or Tape 2. If it is Tape 1 the LED in the switch shows green, if Tape 2 the LED shows red. This switch also selects whether dubbing is from Tape 1 to Tape 2 (LED shows green) or Tape 2 to Tape 1 (LED shows red).

EQ Rec Switch
When pressed this switch puts the equaliser in the circuit to the tape output, otherwise the recording is unaffected by the equaliser settings.

Monitor Switch
This switch allows the recording being made to be monitored through the system without affecting the recording, this is of particular use on three head machines so that the off-tape signal can be checked.

Pink Noise Switch
This switch turns on the internal Pink Noise generator, the output of which is routed to the Line Output sockets. If a microphone is now plugged into the 1/4 inch mono jack socket on the front panel, the equaliser can be adjusted to compensate for the acoustics of the room.

Mic Switch
When this switch is operated the input to the microphone is displayed on the spectrum analyser.

Display Sensitivity Switches
Two switches, one to adjust up and one to adjust down the relative sensitivity of the display, so that low or high level signals can fill the display. The setting has no effect on the output signal.

Graphic/Spectrum Switch
When switched to Graphic the display shows a bar which will move up and down in response to pressing the boost/cut control on each of the 12 channels. In Spectrum mode, the display acts as a spectrum analyser.

Left Channel Switch
Pressing this switch forces the display to show the most recent setting of all the bands on the left channel and any adjustments now made to the boost/cut controls will only affect the left channel. If no adjustment is made, the display automatically returns to Spectrum mode after 10 seconds (unless the Graphic/Spectrum switch is set to Graphic).

Right Channel Switch
As above but for the right channel.

L = R Switch
As above but for both channels simultaneously.

Memory Switch
When pressed, the LED in the switch flashes and when in this condition the current levels of the equaliser settings can be stored by pressing one of the memory preset switches. The indicator on the memory switch will then extinguish. If no memory preset is pressed, pressing the memory switch again cancels the function, and the LED extinguishes.

M1-M4 Switches
Four switches, one for each memory. Pressing the switch recalls an equalisation setting. To store equaliser settings, press the memory switch first.

Flat Switch
Pressing this switch sets all bands to flat (0dB).

Reverse Switch
This switch reverses the equalisation characteristic.

Mute Switch
Pressing this switch instantaneously mutes the output, for example, when answering the telephone. Press again, to restore the output.

Dimmer Switch
The brightness of the display can be varied by pressing this switch, so as to suit daytime or evening light levels.

Peak Hold Switch
With the display in Spectrum mode, the highest level of each band will be held.

Auto EQ Switch
With the Mic and Pink Noise switches set to on, and a microphone connected, pressing this switch forces the equaliser to automatically set up the correct equalisation curve to give a flat frequency response in the room.

As well as all these features, a hand held remote control unit enables the following functions to be adjusted from your armchair: Main level up or down, each of the 12 bands boost or cut, left channel switch, right channel switch, L = R switch, power on/off, memory switch, M1 - M4 switches, graphic/spectrum switch, mic switch, pink noise switch, display sensitivity up or down, mute switch and auto EQ switch.

This fabulous Graphic Equaliser is available from Maplin Electronics at £199.95, their order code number is XM01B.

Air your views!

A readers forum for your views and comments. If you want to contribute, write to the Editor, 'Electronics - The Maplin Magazine', P.O. Box 3, Rayleigh, Essex, SS6 8LR.

Digital Speech

Dear Editor,
I am writing to ask you a question about the Digital Rec/Playback Module in the February/March 1989 edition. Is it possible to interface the module to either the BBC 32k computer or the ATARI 520 STFM computer and use it for sound sampling or as a voice recognition system. If it is possible, could you help me and give me a diagram of how to interface the module to one of the above computers.
Thank you,
T. Kennedy, Lincs, Northampton.

The short answer to whether the Rec/ Playback Module can be used for speech recognition is, yes. As for how to interface the module to the computer, this would involve connecting the computer via a parallel port to the address and data lines of the RAM IC. Some additional circuitry would be required however, to switch between the speech IC and the computer port, to prevent both from trying to access the RAM at the same time. The main requirement for recognition would be a VERY cleverly written computer program, to process and analyse the speech data, the program would need to be written in machine code or a compiled high level language. Maybe some clever readers could help on this one!

MIDI Adaptations

Dear Sir,
I am writing concerning your Digital Record and Playback Module in the February edition. I am a keyboard player and would find this project very useful if it could be adapted to give a MIDI (Musical Instrument Digital Interface) output. Unfortunately, I have very limited experience with electronics, so I would not know where to start. I hope you can help.
Yours,
A. Skinner, Banham, Norfolk.

From your letter, I am not quite sure what you want to do. I assume you were thinking along the lines of a MIDI input so that the Rec/Playback Module could be controlled by a MIDI keyboard. Two things must be bourne in mind about MIDI; firstly MIDI transmits digital control information about the notes being played (and other information), it does not carry any 'sound' or audio signal. Secondly to control things with MIDI some form of data processing is needed to extract the required information and act upon it to produce the required event, this is normally achieved using a small microcomputer. The rec/playback module is really intended for use only with speech, and if sampling with MIDI control is what you are after, it is not suitable. A better idea is a quick trip to your local music store and ask about MIDI Samplers. For more information on MIDI; refer to March to May 1987 issue of 'Electronics' (XA22Y) and the Books section of the current catalogue.

Boxes, Boxes and More Boxes

Dear Sir,
In reply to the Editor and my letter which was in the last issue, may I point out that physically capacitors and diodes also resemble oblong boxes. They appear to be getting sillier all the time at the British Standards Institute, logic gates have been changed to oblong boxes just to add to the confusion. What the objective is, I know not, but our mechanical friends and nuclear workers are also complaining of changes for the worse. Japanese music centres are often marked as Phono. The objects of standards should be to keep things simple. Mho, and Ohm being the inverse is precisely this, Siemens is not.
Yours truly,
Jack Treeby, St. Jades, Plymouth.

The debate on circuit symbols continues! The circuit symbols we use in 'Electronics' are chosen to show as clearly as possible the circuit without ambiguity. I may add, the symbols we use are in common use throughout industrial and commercial electronics. We use the American logic symbols in preference to the British Standards symbols because they are more popular. In this world of fast changinging technology, we have got to be prepared to adapt to the constant changes, otherwise we will be left with diagrams, drawings and terminology that cannot adequately and clearly illustrate what is to be conveyed. With regard to record player/phono /phonogram/ turntable, record player describes exactly what it does, and follows your argument for keeping things simple. Siemens has replaced Mho, but so has Hertz instead of cycles per second!

J Rides Again

Dear Sir,
I think a short answer to Mr. Harms's letter in the December-January issue of 'Electronics', about the interpretation of j = √-1 is worthwhile. He questioned whether j is really √-1, rather than simply indicating a rotation through 90°. This is a convenient way of showing j on the so-called Argand Diagram, but j = √-1 was a mathematical necessity before this graphical way of showing it was thought of.
It is needed as the solution to some quadratic equations, to point out a simple example. Also the expression cos θ + j sin θ can be shown to be equal to ejθ, provided j = √-1. So it does amount to more than just denoting a rotation. On the latest books list, I see you have Martin Hartley Jones's 'A Practical Introduction to Electronic Circuits' (WS19V £10.95) as a new addition. I would like to recommend this to any readers needing a clear and interesting first text that goes beyond the simplest theory. I first read it some years ago, and it gave me sufficient confidence in the subject to take it seriously as a hobby. This eventually lead to my taking formal qualifications in electronics at the end of last year. As I started out with a degree in a biological subject, you can see what a vast change was eventually wrought.
A. Atkinson, Newton Aycliffe, Co Durham.

Colourful Computers

Dear Sir,
The article commencing on P48 of the Dec 88/Jan 89 issue, failed to tackle the problem of the case where the computer outputs (i.e. colour, sync and blanking) are not in the form as required by the TEA 2000. A typical case, in this respect is the Amstrad CPC 6128 and this situation can present difficulties to the constructor when interface information is not readily available or obtainable. It is suggested therefore, that an addendum to the article is prepared, that, for typical computers (including the CPC 6128), will provide the necessary information to fill the gap and dispell the frustration that lack of information generates.
Yours hopefully,
R. W. H. Davis, Dorchester, Dorset.

With projects such as the TEA 2000 PAL Encoder, having such a wide range of applications, it is impossible for us to predict every possible use it will be put to and for this reason we cannot always provide data or connection details to other pieces of equipment, such as computers. This is not helped by the very wide range of computers available and a lack of standardisation by manufacturers. The time it takes to collate information of this nature would tie up our Lab engineers and prevent them from developing projects. It is really down to the individual constructor to fully read the text with the project and decide whether he has enough information/experience to achieve the desired aim, BEFORE purchasing the parts or kit. However, if another reader can provide us with suitable information, we will always consider publishing it.

Electronics Going Rusty

Dear Editor,
Congratulations on updating to your bi-monthly magazine 'Electronics'. At Maplin you've built up a reputation for bringing us, your customers, the new and individual. Often your ideas are exclusive, and I must add exceptional value.
This brings me to my point, over the last few months I have noticed that there is a new product in the car accessory shops, a device for stopping rust from forming on the car body. It would appear that as metal oxidises to form rust, it generates a small electrical current. The device senses this and counters it with a charge of the opposite polarity, the result being rust is unable to form. Now I notice that projects for cars in your Top 20 list is quite high, and because of this I think a project for a device of this type would be a very popular choice with your customers, myself included.
R. H. Thorne, Wolverhampton, West Midlands.

Yes we've seen them as well, and the Lab may be doing some research into the subject of electronic rust prevention. Meanwhile, if any readers (calling all metalurgical experts!) have any ideas, comments or circuits, please write in.

Intergalactic Letter

Greetings,
Your supply freighter, the 'Capella II', has recently visited Central Worlds bringing electronic components and associated literature. During routine translation into Galacta of your 'Buyer's Guide' an error report was generated by the itenerary of the 'Capella II' on page 3. My colleagues in the Social Studies Department insist that you should be notified to avert what they refer to as 'bad PR' in the Sirius Sector and beyond. The error report came from the eighth line of text which begins; "and world's team in profusion. And along the way..."; Analysis suggests that this line should read; "and worlds teem in profusion. And along the way..."
178226 Tyerman, University Library, Trantor, Federation of Central Worlds.

It's great to hear from all you long distance customers, please thank your language experts for their comments. (The caption writer has been sent off to evening classes to study GCSE English!)

Electronics Under Glass

Dear Sir,
With reference to Dave Goodman's article on temperature modules, Volume 7 number 25. I am considering using the FE33L module as a glasshouse temperature controller. The problem being, in the event of a short mains failure, the set temperature markers are lost. Is it possible to show how back up battery power can be provided to the module (if only dry battery). I'm sure this would be of use to many of your readers.
Yours faithfully,
D. Lamer, Great Yarmouth, Norfolk.

Firstly, read through the article published in the magazine to ascertain that you can achieve what you want with the project. Regarding standby battery supply, if you are using the serial to parallel converter, which I assume you are, a suggestion would be to connect an additional 1N4001 to D3. The cathode of the additional diode should be connected to the cathode of D3 (the end which connects to pin 1 of RG1). The normal 12V supply shoud by connected to PL3 as before and the standby (battery) supply +V connected to the free end (anode) of the additional diode, the 0V should be connected to pin 2 of PL3. The standby supply voltage should be greater than 7.5V and the normal supply at least 2V higher than the standby supply (e.g. 9V and 12V respectively), this is to ensure correct switching between supplies. Remember, this is a suggestion for your own experimentation.

One-man Band

Dear Sir,
You invite readers to contibute further applications for the Digital Record & Playback Module. Are you giving away any free kits for the most original use? I am a musician and entertainer, and part of my work is inventing and operating one-man bands. Increasingly, I am using electronics for control, though for entertainment value there is no substitute for visible mechanical effects. My most recent one-man band is a full size dummy chimpanzee 'playing' real drums with solenoid operated beaters. The solenoids are triggered in real time from the bass and chord buttons of my piano accordian. Now this monkey has a friend, a stuffed macaw, who, as yet has not learned to speak! The band and I therefore await with eager anticipation the playback version of the project.
Yours sincerely,
H. Barwell, Nottingham.

Look no further than page 64 for the continuation boards; the Playback Only and EPROM Modules.

Lionel Jeans 88

Evening on the planet Oldana, as the Maplin Juggertrain thunders along the highway; captured on canvas by galaxy famous artist Lionel Jeans and featured on the cover of the new Maplin Catalogue.